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Editorial

Traditionally all abstracts of contributions submitted to the 23rd General Assembly are included free of charge in the *Annales Geophysicae Supplement* once they were accepted by the appropriate convener(s) and once they were received in time, in the standard format and of sufficient quality for reproduction. Abstracts submitted for symposia included in two different parts of the Supplement issue are included (twice) in both parts, respectively.

Like in previous years, not all contributions included will actually be presented. Because of the lack of financial support, several young scientists as well as colleagues from the central and east-European countries will not be able to participate in the meeting, although the Society has continued its support schemes, such as the Young Scientists' Travel Award and the East European Support Award. In this way there are more abstracts included in the *Abstract Book* than contributions compiled in the *Programme Book*. Therefore, in order to simplify the ordering of abstracts within an event, we have adopted the alphabetical order with respect to the surname of the first author rather than the order of presentation in the *Abstract Book*.

With almost 5.800 contributions received, this Supplement of *Annales Geophysicae* has become an important open forum for fast distribution of results of geophysical research on a pan-European, international level, helping, at the same time, to promote the contact between all geophysicists in Europe. Please, support the fostering of cooperation and contact your colleagues also if not personally present this time. For this reason, the authors have also included a contact e-mail or fax number in their abstract for faster correspondence.

On behalf of the Society I am very pleased to welcome you to Nice on the occasion of the 23rd General Assembly of the European Geophysical Society. May your participation in this meeting be successful and scientifically rewarding.

A.K. Richter
Executive Secretary

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SOCIETY SYMPOSIA (EGS)

EGS1 Tribute to Stephan Mueller

01 Tectonics, structure and dynamics of the Alpine- Mediterranean System

Convener: Ansorge, J.
Co-Conveners: Banda, E.; Kahle, H.-G.

PALEOMAGNETISM AND PALEOGEOGRAPHY IN THE MEDITERRANEAN

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It is now over 20 years since the African affinity of paleomagnetic data from deformed Mesozoic continental margins surrounding the Adriatic Sea (Adria) was first recognized. The sense and scale of thrust sheet rotations has now been well documented in some parts of the belt, and has played an important role in reconstructing the paleogeography of the continental margins. Large-scale rotations have been recognized in Sicily, throughout the Apennines, in the Dinarides and Hellenides and in the Northern Calcareous Alps/Bakony Mts. In a few places, such as Umbria, APWPs from individual thrust sheets appear to have "African" shape. Unlike most of the deformed continental margin of Adria, significant differential rotation of thrust sheets in the Southern Alps is not widespread and is restricted to the immediate vicinity of major faults such as the Insubric Line and Valsugana line. Permian to early Cenozoic paleomagnetic directions are generally consistent across the Southern Alps, from Friuli in the east to the Lombardian Basin in the west. The composite APWP from the Southern Alps for Early Permian to Cenozoic time, and individual poles from the para-autochthons (Iblei, Apulia/Gargano, Istria) coincide with best estimates for the African APWP, within the uncertainties associated with both datasets. It therefore appears that Adria has rotated with Africa since Early Permian time in spite of evidence for Mesozoic oceanic extension in the position of the present-day Ionian Sea, and extending eastward into the eastern Mediterranean.

Tectonic modelling of sedimentary basin formation in the Alpine - Mediterranean: developments and perspectives.

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The Alpine-Mediterranean area offers a number of excellent natural laboratories to study the dynamics of sedimentary basin formation. Data sets obtained through a large array of multidisciplinary observational approaches provide important constraints on, for example, the mechanisms of extensional basin formation in convergent regimes, the interplay of extension with simultaneously occurring compressional fold-and thrust belt development and the causes and effects of late-stage compressional reactivation of extensional basins. We review the interplay of lithospheric processes and the surface processes in a number of basins in the area using quantitative modelling for the reconstruction of the basin fill and the associated record of vertical motions as well as for an assessment of the role of paleo-rheology in the process of sedimentary basin (de)formation.

GEODYNAMICAL MODELLING : GLOBAL MANTLE DYNAMICS AND SEISMIC TOMOGRAPHY

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Lithospheric plate velocities were first described on the basis of the present sea floor age pattern, in coherence with focal mechanisms of earthquakes near plate boundaries. Why the plates are moving remained however an unanswered question until seismic tomography started to reveal weak lateral heterogeneities besides the strong radial dependence of seismic velocities. This enabled mantle dynamicists to introduce corresponding density loads in mantle models, the viscosity of which had already been estimated by post glacial rebound models. This presentation will describe the successes of mantle dynamics in predicting plate velocities and the shape of the geoid, i.e. of the perturbed gravitational potential. The role of subducted material in driving plate motion has thus been confirmed. In addition the deep mantle mass anomalies responsible for the long wavelength geoid were shown to derive from slabs as old as 100 or 150 Ma, which penetrated the lower mantle. New higher resolution tomographic results confirm this ongoing simple flow pattern.

CENOZOIC RIFT STRUCTURES IN THE SURROUNDINGS OF THE ALPINE-MEDITERRANEAN SYSTEM

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Two major rift systems developed at the edges and in connection with the Alpine - Mediterranean orogeny: the Central European rift system bends around the arc of the Western Alps and the Afro-Arabian rift system starts in the Levante at the southeastern end of the Mediterranean. This contribution emphasizes the most important crustal and upper mantle features of the Central European rift system as mainly based on seismic and seismological investigations. Under the Rhenish Massif, taphrogenesis may just have started or has been severely disturbed by the concrete block of the Rhenish Massif. In some regions it seems that only the upper part of the crust was affected by the rifting. In other parts of the rift, possibly controlled by faults of crustal dimensions, the lower crust has been modified by rift-related processes as well. For the southern segment of the Rhinegraben, new seismic data require to assume a two-level plate tectonics with a zone of decoupling between a brittle upper part, broken into blocks of different sizes, and a ductile lower part of the lithosphere. The asymmetry of the deep hypocenter seismicity, the thinning of the lower crust and the deepening of the reflective lower crustal layer may be caused by the activation of an intracrustal detachment horizon in reponse to the built-up of intraplate compressional stresses related to collisional coupling of the Alpine orogen with its foreland. The Moho depths compiled for the European Cenozoic rift system may not always be identical with the petrological, real crust-mantle boundary.

NEOGENE-QUATERNARY MAGMATIC ACTIVITY AND ITS GEODYNAMIC IMPLICATIONS IN THE CENTRAL MEDITERRANEAN REGION

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The petrogenesis and time / space distribution of the magmatism associated with the formation of the northern and southern Tyrrhenian basins show that the two arc / back-arc systems are separate by a lithospheric discontinuity at about 41° N and underwent a different structural evolution at least since the Middle Miocene (Langhian).
The geochemical components involved in the genesis of the hetherogeneities of the mantle sources of this magmatism require two separate, compositionally different slabs: 1) an old oceanic (Ionian) lithosphere still seismically active below the Calabrian arc and the southern Tyrrhenian region; 2) an almost seismically inactive continental (Adriatic) lithosphere. The proposed geodynamic models require: 1) for the northern Tyrrhenian /northern Apenninic "arc / back-arc system", the delamination and foundering of the Adriatic continental lithosphere which has taken place as a consequence of the continental collision between the Corsica block and the Adriatic continental margin. This delamination process, which is still ongoing, has probably started in the Early-Middle Miocene.
2) for the southern Tyrrhenian / southern Apenninic-Calabrian arc / back-arc system, the roll-back subduction and back-arc extension driven by gravitational sinking of the Ionian oceanic subducted lithosphere. This process has probably started just after the end of the arc volcanism of Sardinia (about 15-13 Ma).

SEISMICITY AND STRESS REGIME IN THE MEDITERRANEAN REGION

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Distribution of hypocenters and focal mechanisms of earthquakes are the basic tools in establishing the seismicity and stress regime in a region. The Mediterranean region is located at the plate boundary between the Eurasian, African and Arabian plates. This boundary extends from the Azores islands to the Caucasus and has a complex nature with interaction of oceanic and continental lithosphere. Seismicity varies in degree from area to area, with higher activity in the Hellenic arc. Most earthquakes are of shallow depth with four regions of deep and intermediate foci related with arc structures. The boundary separates continental and oceanic lithosphere with the presence secondary blocks, areas of extended deformations and subduction zones. Regional stresses show predominant horizontal compressions in a general NW-SE direction with some areas of horizontal tensions in the Betic-Alboran, Apennines, northern Greece and western Anatolia.

EGS1 Tribute to Stephan Mueller

02 Evolution of the African-Eurasian plate boundary

Convener: Channell, J.E.
Co-Conveners: Jacoby, W.R.; Zerbini, S.

PLIOCENE TO PRESENT STRESS-FIELD EVOLUTION OF THE CENTRAL APENNINES ADRIATIC MARGIN (ITALY): AN INTEGRATED GEOPHYSICAL APPROACH

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An attempt was made to integrate different geophysical data sets to reconstruct the time-spatial evolution of the stress field in the foredeep to foreland Adriatic margin of the central-northern Apennines, during the past 5 Ma. We used an updated compilation of borehole breakout in deep wells (about 50 wells) and focal mechanisms of $2.5<Md<4.5$ crustal earthquakes that occurred in the last year to determine the present stress field in the area. The anisotropy of magnetic susceptibility of marine fine-grained Plio-Pleistocene sediments (27 sites of sampling) was used to evaluate the temporal evolution of the strain pattern in the area. A synthesis for these geophysical data is discussed in terms of their bearings to the tectonic evolution of the region.

THE EVOLUTION OF THE ALPINE-MEDITERRANEAN REGION: FROM STRUCTURE AND KINEMATICS TO DYNAMICS

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Results of seismic tomography studies on the 3D mantle structure of the Alpine-Mediterranean region are the basis for our quantitative approach of the lithospheric dynamics in the region. We emphasize the following aspects and results: First, through a test via thermo-kinematical modelling the tomography results have provided strong support to reconstructions such as the one by Dercourt et al. (1986). Secondly, on the basis of the tomography results for the Alpine-Mediterranean region we have hypothesized (Wortel and Spakman, 1992) that (a) lithosphere subducted in the Alpine-Mediterranean convergence zones has become detached from the near-surface lithosphere, and (b) the detachment has propagated (or migrated) laterally along the strike of the convergence zones. This hypothesis has been (and is) subjected to three types of tests: (1) a numerical modelling study of the mechanical aspects of the proposed process, (2) a test of model predictions against pertinent geological, geophysical and geodetic observations, and (3) additional tomographic resolution tests, specifically aimed at the question whether the tomographic results allow for the interpretation of detachment. The test results provide increasing support for the hypothesis of lateral migration of slab detachment, and for the significance of the process in the geodynamical evolution of the region.

STRUCTURE OF THE ALBORAN BASIN, TECTONICS AT THE IBERIA-AFRICA PLATE BOUNDARY FROM NEOGENE TIMES

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The Alboran Basin has been evolving since Neogene times within the internal zone of the Betic-Rif orogen, at the Iberia-Africa transpressional plate boundary. Extensional processes during Early Miocene times initiated the basin, and was coeval with shortening in the external zone of the orogen. Since the late Tortonian, a dominant strike-slip tectonic regime has been influencing the structure of the basin. Timing of events are partially constrained by borehole data at the northern margin and ODP Leg 161 drilling at deeper parts of the basin. The ESCI-Alb multichannel seismic survey imaged the crustal structure of the Alboran Basin in two profiles, both showing sub-basins filled with Miocene to Recent sediments between fault-bounded basement highs and/or volcanic edifices. The ESCI-Alb1 is a 90 km long NNE-SSW trending profile across the northern Alboran Sea margin. It images gently basin-ward dipping reflections at 6-8 s interpreted to correspond to a detachment surface within the crust near the Spanish margin. Layered lower crustal reflections are at 6-9 s near the centre of the basin. The ESCI-Alb2 is a 298 km long E-W trending profile from the central part of the Alboran Sea to the South Balearic Basin. Westward tilting of basement blocks appears to have occurred during Pliocene to Recent times. The ESCI-Alb data, together with other multichannel seismic profiles, provide evidence suggesting that strike-slip tectonics is playing a significant role in the present morphology of the basin, and that active left lateral transpression related to oblique convergence between the African and Iberian plates continues to influence the development of the Alboran region.

MODELLING OF TERTIARY TO PRESENT DAY STRESS FIELDS IN THE IBERIAN PENINSULA AND RELATED INTRAPLATE DEFORMATION

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The Iberian Peninsula experienced from E Tertiary onward stress fields that changed rapidly in type, orientation and magnitude. Oblique collision with Eurasia starting in L Cretaceous- E. Paleogene created a stress field with Shmax oriented NNW-SSE, rotating in time to N-S or NNE-SSW with major deformation in the Pyrenees and off shore Cantabria. A jump in active plate boundary to the south in M Miocene relocated the major deformation front to the Betics and caused an uniaxial compression, with Shmax NNW-SSE. Opening of the Valencia Trough to the E side of the plate readjusted this stressfield during L Miocene to extension in the Valencia area and strike slip in the interior of the plate. Due to the ongoing convergence between Africa and Eurasia/Iberia the NNW-SSE compressional stress field has been reactivated from L Pliocene. Several overlaps in time and place of the described regional stressfields caused very diverse local stress fields. Most of these stress stages are well documented in the deformation of the interior of the plate. Field data (micro- and meso-structural) provide constraints for the orientation of the stressfield through time and place. The results of first order numerical modelling of the (paleo)stress fields by plate boundary changes and differential opening of the North Atlantic are compared with the obtained stress trajectory maps for different timeslices from E Tertiary onward to test hypotheses on the evolution of both plate boundaries of the Iberian microplate as well as its internal deformation.

CENOZOIC AFRICA-EUROPE CONVERGENCE IN THE CENTRAL MEDITERRANEAN: KINEMATICS AND GEOLOGICAL IMPLICATIONS

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The convergence between the African and European plates has been going on from late Cretaceous to Present and the motion between the two major plates were established from modelling of the magnetic anomalies in the Atlantic ocean. However, the reconstruction of the position of Adria through time suffered from the lack of major constraints and, depending upon the authors, this continental block was considered either as attached to the African plate as a promontory or as an independent microplate.
Multichannel seismic profiles collected in the last few years by the Institute of Marine Geology of Bologna in the Adriatic area allow to disregard the hypothesis of a Tertiary microplate boundary between Adria and Africa and support, instead, a recent review of paleomagnetic data that indicates an African affinity of Adria during the Jurassic and Cretaceous. Considering the solid connection between Africa and Adria throughout the Mesozoic, and using some simple assumptions derived from the inferred geodynamic processes, a kinematic reconstruction of the Central Mediterranean, from late Cretaceous to the Present will be presented. Controversial aspects such as the Alps-Apennines connection, the flip of subduction polarity and the repositioning of the subducted portions of the Tethyan oceans can be fit in the proposed evolution.

LITHOSPHERIC PROCESSES IN THE PROVENÇAL AND TYRRHENIAN OCEANS CONTROL THE VELOCITY OF SUBDUCTION IN CALABRIA (SOUTHERN ITALY)

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During the Paleogene Corsica-Sardinia and Europe formed a single continent. To the SE, continental collision with the Adriatic plate was nearly complete. In the Late Oligocene, Corsica-Sardinia and Adria began rotating counterclockwise leading to the opening of the Provençal ocean first and, subsequently, of the Tyrrhenian ocean. Continental rifting in the Provençal basin ended in the Early Miocene and was followed by oceanic spreading. In the Burdigalian the oceanic ridge was de-activated and extension shifted east of Corsica-Sardinia. The persisting rotation of Adria caused rifting between the two blocks and, eventually, the formation of oceanic crust in the S-Tyrrhenian basin. The dynamics of extension in the area was basically controlled by the sinking and roll-back of the subducting Ionian plate. In the initial stages, stresses and deformation were distributed over the entire upper plate between Spain and Calabria. Retreat velocities at the SE edge of the upper plate were low, in the order of few mm/y. With the abandonment of the Provençal spreading, stresses were distributed over a shorter length between Sardinia-Corsica and the SE plate edge and velocities in Calabria increased to several mm/y. The acceleration of Calabria is documented bv geological evidence.

SEGMENTATION AND SEISMICITY OF THE CYPREAN ARC

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The Cyprean Arc is divided into three distinct segments. In the western segment normal subduction takes place. The relative plate motion is almost perpendicular to the arc in this segment. In the central segment a collision between Eratosthenes seamount and the arc occurs. In the eastern segment the arc forms a wide zone of wrench faulting. We determine the centroid depths for the Mw=6.8, October 9, 1996, Cyprean Arc earthquake, located west of Cyprus, and its largest aftershock to 32 and 27 km, respectively, by modeling P and SH waveforms. The actual fault plane was found from the distribution of aftershock events and from the location of the Harvard centroid solutions of the mainshock and its largest aftershock. We also calculated the pole of motion between Anatolia and Africa and determined the relative plate motion between these plates. The strike-slip mechanism, unusual for a subducting plate, may be caused by locking of subduction south of Cyprus, where the continental Eratosthenes seamount underthrust Cyprus. The result appears to be the emergence of a strike-slip tear fault between the western and the central segments, separating the continental Eratosthenes seamount south of Cyprus from the oceanic African lithosphere that subducts west of Cyprus.

NUMERICAL SIMULATIONS OF THE SURFACE EFFECTS OF SLAB DETACHMENT: THE APENNINES

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Regional tomographic images of Adriatic lithosphere, subducted below the Apennines (Italy), suggest that it is detached. Wortel and Spakman (1992, *Proc. KNAW 95*) hypothesize that this is the result of propagation of a horizontal tear along strike of the convergent plate margin. This may lead to the following surface expressions. A more pronounced outward migration of the trench and a deeper surface deflection are expected to result from the transfer of the weight of the detached part of the slab to the undetached part. Rebound occurs where the slab is detached and slab pull is reduced.
We employ a two-dimensional viscoelastic model to simulate the surface effects of detachment of subducted lithosphere. Paleogeographic reconstructions are used to constrain the initial geometry of the model. Movements of the side boundaries are constrained by paleomagnetic observations. Mechanical boundary conditions at the bottom of the model can be used to represent the effects of the slab well below the region of interest. In the simulations, the evolution of the model interior is governed by the dynamics of the process under consideration. We focus on detachment induced changes in horizontal and vertical motions and compare the results with geological observations for the Apennine subduction zone.

$^{40}Ar/^{39}Ar$ EVIDENCE OF AN EO-ALPINE EVENT (128 Ma) IN GREATER KABYLIA (ALGERIA): GEODYNAMIC CONSEQUENCES.

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A ductile shearing event is recognized in gneisses and barite veins of the crystalline internal massifs of alpine Maghrebides. Dating of shearing movement is carried out by $^{40}Ar/^{39}Ar$ laser-probe experiments performed on synchronous neoformed micas. The proposed age at 128 Ma is constrained by a two-components mixing model for the saddle-shaped age spectra on phengites and by a plateau age at 128.3 ± 0.3 Ma on muscovite. This Hauterivian-Barremian boundary age records a strong reworking of the Alboran plate (input of detritals in the flysch basin) and surrounding areas and can be correlated with the J magnetic anomaly in the Atlantic and the distensive events in the Pyrenees and external Alps. Therefore, dispersed radiometric ages (130-80 Ma) obtained on the alpine-Mediterranean basement could reflect interferences between this event at 128 Ma and late-alpine stages.

THE ACTIVE TECTONICS OF THE AEGEAN REGION: INSIGHTS FROM NUMERICAL MODELS

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The Aegean region is characterized by a very fast and interesting geodynamics. Different processes like continent-to-continent collision, subduction, internal extension occur in this area. On one side, the observed velocity field can be simply described as a rigid rotation of the Aegean plate. On the other side, our results suggest that this rotation be due to the interplay between the push of the Arabian plate, the effects of the sudbuction of the African plate, and of the disomogeneity of the Aegean plate regarding the crustal thickness and the heat flow at the surface. In this paper we test the effects of different mechanisms by a 2D finite element model with realistic rheology for the crust and lithospheric mantle. Our aim is to find the distribution of forces and boundary conditions at the border of the plate that can reproduce better the observed velocity and stress fields.

WILSON'S AND BERTRAND'S CYCLES IN THE EVOLUTION OF THE MEDITERRANEAN AND URAL-OKHOTSK INTERCONTINENTAL MOBILE BELT

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In the evolution of the mobile belts and of the paleooceans from which they originated, it seems rationally to distinguish cycles of two orders: the largest among them comprises the time elapsed from the beginning of the breakup of a supercontinent and birth of a paleoocean until the closure of this ocean and the formation of a new supercontinent . Such megacycles, with duration of an order of 500-600 mln years, correspond in the author's opinion to the cycles established by J.T.Wilson and deserve to be named after his name. The megacycles consist of shorter cycles, of an order of 150-200 mln years, which correspond to the classical cycles distinguished by M.Bertrand - Caledonian, Hereynian, Alpine , later suplemented by Baikalian and Cimmerian. These cycles are characterized by a partial closure of separate parts of the oceanic basins, due to the collision of microcontinents with the continents, bordering this ocean, and by simultaneous opening of new basins in its other parts. An even shorter category of cycles could be noticed - cycles, separated by Stille's "orogenic phases", following each other after 20-25 mln years (Stille's cycles"). These orogenic phases are provoqued by the collision of volcanic island arcs with each other or microcontinents or continents.
All the above said could be illustarated on the example of the evolution of the two largest intercontinental mobile belts of the Eastern hemisphere: the

THE POSITION OF THE AFRICAN-EURASIAN PLATE BOUNDARY DURING THE PERMIAN TO JURASSIC

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The closure of the northern Hercynian ocean accreted detached splinters of the African Plate to the European Plate. In the south, a Hercynian remnant ocean remained open until an Artinskian to Roadian subduction (Lercara flysch in western Sicily, similar sequences in Mrzle Vodice, Croatia, and "clastic Trogkofel Beds", Slowenia) that closed parts of this basin (e.g., Mrzle Vodice), whereas other parts continued into the Mesozoic (Oman-Sicily Belt). As shown by the African rotation pattern of the Adriatic Plate, this remnant ocean was part of the African Plate. North of this remnant ocean, an oceanic trough (Antalya-Mamonia-Pindos-Budva Ocean) opened during the upper Olenekian to middle Carnian. Further in the north, during the latest Permian and Lower Triassic (northwestern Turkey) or during the Lower Anisian (Meliata-Hallstatt Ocean), the Cimmerian Ocean opened within the Eurasian Plate separating a part of the Hercynian accreted originally African southernmost Eurasian Plate (Cimmerian Microcontinent). Southward-directed subduction of the Cimmerian Ocean caused the Late Triassic-Jurassic opening of the Vardar-Izmir-Ankara Ocean within the Cimmerian Microcontinent. In the Jurassic, the Penninic Ocean opened north of the Meliata-Hallstatt Ocean within the Eurasian Plate. The Permian-Mesozoic oceanic troughs, partly with interacting opening and closing, separated several Western Tethyan microplates that were neither connected with the African nor Eurasian plates.

TELESEISMIC IMAGING OF THE VRANCEA ZONE, ROMANIA

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The Vrancea zone seismicity has peculiar features: (i) strong earthquakes in intermediate depths occur in a very narrow volume; (ii) this seismogenic zone is situated beneath continental crust; (iii) no evidence for active ongoing subduction is found today. Our teleseismic tomography study gives new evaluation of tectonical scenarios related to the Vrancea seismicity. The digitally recorded waveforms for 125 events mainly from the period between 1994 and 1997 were picked, travel-time residuals were calculated with the IASP91 reference tables and the inversion was done with the ACH-method. The weighted relative residuals, which are more or less independent of hypocenter localisation errors, were minimized using a standard least squares algorithm. Our current best fit model with a variance improvement of 70 per cent has some prominent features: (i) the local high velocity body with maximum perturbations of about 3 per cent is totally embedded in a low velocity medium with negative peak perturbations of about 5 per cent; (ii) indication for break-off in about 120 km depth; (iii) a downward counter-clockwise rotation of the subducted slab from southwest-northeast orientation to south-north orientation. Our slab model is an image of the Eastern Carpathian subduction zone which retreated towards the east during middle Miocene and changed its direction towards southeast during the final stage in late Miocene.

BELT BENDING AS A CONSEQUENCE OF LATERAL BENDING OF SUBDUCTING LITHOSPHERIC SLAB: GEOPHYSICAL EVIDENCES FROM THE NORTHERN APENNINES (ITALY)

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In this paper we explore the possibility that the arcuate shape of the northern Apennines is a consequence of the lateral bending of the subducting Adriatic plate. Recent paleomagnetic results from the northern Apennines document that this belt is properly an orocline and results from early Pliocene bending of a Messinian straight belt-foredeep system. Tomographic images in turn show the presence of an high-velocity body, interpreted as an active subducting slab, in the upper mantle beneath the northern Apennines between 35 and 670 km of depth. Up to 100 km this body displays an arcuate shape which mirrors the geological outlines, while it progressively straightens itself at depth. We speculate that northern Apennines arc formation, shown by paleomagnetism, closely follows in time the lateral bending of the subducting Adriatic plate. This implies that widespread extension and high thermal flow along the Tuscan Tyrrhenian margin is a consequence of bending of subducting Adriatic lithosphere and subsequent larger amount of north-eastward displacement in the central part of the belt caused by trench suction forces. These new geophysical data from the central Mediterranean seem thus to demonstrate that the surface setting is strongly controlled by deep processes.

NUMERICAL SIMULATION OF THE RECENT/PRESENT KINEMATIC PATTERN IN THE CENTRAL-EASTERN MEDITERRANEAN AREA.

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The kinematic pattern in the central-eastern Mediterranean region has been tentatively reproduced by finite element modeling, involving 2-D elastic shells in a plane stress approximation. The model is constituted by a mosaic of poorly deformable "blocks" separated by much more deformable "decoupling zones", representing consuming borders, extensional zones and transcurrent discontinuities, whose location and geometry has been deduced by neotectonic, morphological and seismological information. The deformation of the model is obtained by imposing kinematic boundary conditions which simulate the presumed motions of Africa and eastern Anatolia with respect to Eurasia. It is argued that the limitations of the simplified modeling approach adopted should not crucially affect the reliability of the results in the limited time interval considered (thousands of years). Numerical computations indicate that the boundary conditions and structural-tectonic setting adopted may provide a good fit of the observed strain regimes, even for the zones affected by extensional tectonics, in spite of the overall compressional regime imposed to the model. The calculated displacement field obtained with the modeling parametrization which allows a satisfactory fit of the observed strain regimes is compatible with the available geodetic observations in Anatolia and central Mediterranean, but cannot reproduce the high motion rates suggested by geodetic data in the central-western Hellenic Arc. Possible causes of this discrepancy are discussed.

MEDITERRANEAN EVOLUTION: A SIMPLE INTERPRETATION BASED ON THE MINIMUM WORK CONDITION

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The apparently complex space-time distribution of compressional and tensional deformations in the central-eastern Mediterranean since the Middle Miocene may be coherently interpreted as a consequence of the basic physical requirement of minimizing the total work of horizontal forces, induced by the convergence between Africa-Arabia and Eurasia, against the forces resisting lithosphere consumption and crustal shortening. This concept, in particular, implies that when the resisting forces at a consuming boundary undergoes a significant increase, due for instance to the arrival of continental crust at a the trench zone, the system may find it convenient to stop the highly resisted consuming processes and activate other subduction zones through lateral extrusion of crustal wedges. This scheme may coherently account for the drastic changes of tectonic style that occurred in the region considered around the Middle Miocene, the late Miocene and the late Pliocene-early Pleistocene.

TERTIARY COUNTERCLOCKWISE ROTATION OF ADRIA AS EVIDENCED BY NEW PALEOMAGNETIC DATA FROM ISTRIA AND NW DINARIDS

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It is generally accepted that Adria, as an indenter, played key role in the tectonic development of the Central Mediterranean. However, some define it as an African Promontory, rigidly attached to the African plate, others are of the opinion that Adria is a microplate.
In order to obtain more data relevant to this problem, a paleomagnetic study was undertaken on K/T boundary trough Lutetian rocks, between the Idria fault, recognized as the zone of recent decoupling (accompanied by CCW rotation) of Adria and the southernmost promontory of Istria peninsula.
As a result, the following pattern of the paleodeclinations can be seen: In "autochthonous" Istria they are 320-330°, thus supporting the existence of an Adriatic microplate rotating counterclockwise with respect to both the African and European plates, in post mid-Eocene times. Rotation in the same sense is slightly larger in the fold belt, at the neck of Istria peninsula. Further to the N, the declinations change to 10-20°. This situation suggests that, the paraautochthonous Dinaridic chain consists of two parts: the southern thrust sheets must have rotated together with the Adriatic microplate, while the northern ones in the opposite sense.

LITHOSPHERE DYNAMICS AND VOID - VOLATILE INTERACTION IN THE EUROPEAN ALPINE COLLISION

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When continents collide fluids are inherited from the previous oceanic and continental subduction processes. Andesitic volcanism, the most efficient transfer mechanism of subducted volatiles, is shut off after collision. The remnant fluids may find their way to the surface, through the deforming upper mantle, or are buffered in metasomatic alteration products. In this study the important role of volatiles in the continental collision process is estimated numerically. A ductile void nucleation and growth criterion is applied. For a critical void volume accelerated void growth is allowed and the associated mechanical weakening can cause localized faulting ("ductile fracture"). The model considers 3-D punch indentation, where Italy/Adria represents the punch and Europe the deformable medium. Volatiles are found to be swept far inland into an area where tensile deformation occurs. Volatiles in the compressive field close to the punch vanish due to negative void growth. A ductile fault is predicted to cut through the European Plate. Possible application to the Rhine, Bresse, Limagne Graben system is discussed.

MODEL ANALYSIS OF THE EVOLUTION OF INTRA-PLATE STRESS IN THE CENTRAL MEDITERRANEAN

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The region of the Ionian Sea and Adriatic Sea plays a central role (literally) in the Cenozoic evolution of the boundary zone between the African plate and the Eurasian plate. It is through the lithosphere that underlies this region (the "African promontory") that compression associated with the Africa-Eurasia convergence is transmitted to the Alps and other parts of western Europe. Moreover, the subduction zones that flank the region to the west and east are a key dynamical factor in the tectonics of the Tyrrhenian Sea-Apennines and Aegean region.

We adopt a numerical model to investigate the temporal evolution of the intra-plate stress field of the Ionian and Adriatic Sea and adjacent areas. Stress fields are computed for various distributions of the acting forces and for various points in time since the Early Oligocene. Our objective is to gain insight into, (1) the effect of the change in geometry of the promontory with time, (2) the effect of detachment of the slabs of subducted lithosphere attached to the sides of the promontory. We address the consequences these factors have for the state of stress in the adjacent land areas and for the development of subsidence in the foredeep of the Apennines.

LITHOSPHERE AND MANTLE STRUCTURE BELOW THE AFRICAN AND EURASIAN PLATES

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We present new tomographic images of lithosphere and mantle structure below the Eurasian and African plates obtained from global mantle tomography (see: Bijwaard, Spakman, and Engdahl, this meeting). In contrast to previous global mantle models, the model of Bijwaard et al. possesses the small (50-100 km) detail characteristic of the relatively high-resolution regional tomographic models as forstance for the Alpine-Mediterranean region. We will demonstrate that, generally, a good correspondence is obtained between the regional mantle models and the recently obtained global model. Differences exist but can largely be attributed to differences in data quality, reference models used, and differences in mantle sampling. We will review and discuss the structure of the upper mantle in the Alpine-Mediterranean region and shed light on its relation to the destruction of the Tethys ocean. The Tethys ocean is imaged as an assembly of elongate, roughly NW-SE oriented structures, extending from the Eastern Mediterranean to SE Asia at depths between 1000 - 2000 km in the mantle. We will also discuss the huge lower mantle anomalies that are possibly related to upwelling of hot material and that can be followed from the Iceland plume to western Europe, the Mediterranean, northern Africa up to the Canary islands. These upwellings may have fed the important volcanic complexes in Western Europe, such as the Eifel and the Massif Central.

DYNAMIC MODELLING OF CRUSTAL MOTIONS AND SEA-LEVEL CHANGES RELATED TO SUBDUCTION AND CONVERGENCE IN THE CENTRAL MEDITERRANEAN

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Crustal deformation in the central Mediterranean is modelled by means of three-dimensional finite element models assuming a viscoelastic rheology. The tectonic mechanisms under investigation are subduction of the Ionian lithosphere underneath the Calabrian Arc and the continental convergence between Eurasia and Africa. Modelling results concerning horizontal sufare motions are compared with geodetic VLBI and GPS observations, whereas vertical motions are compared with the neotectonic map of Italy. Due to the overthrusting of the Tyrrhenian domain onto the Adriatic one, the horizontal velocity at the eastern boundary of the Tyrrhenian domain rotates to the East, in agreement with geodetic observations. The vertical motions are characterized by subsidence of the Tyrrhenian Sea, the Adriatic and Ionian foredeeps, and by uplift of the Apennines. Calculated roll-back velocities are clearly smaller than those inferred from gelogical studies. Two-dimensional models built for the geologic past indicate roll-back velocities of several centimeters per year, in agreement with geological estimates.

PLATE-TECTONICS OF THE CARPATHIAN ARC

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New kinematic data from the bending regions of the Carpathian arc were combined with sedimentological and paleomagnetic data to develop a geodynamic model for the Neogene tectonic evolution of the Carpatho-Pannonian region. It is characterized by the independent rotation and translation of two microplates which gradually occupied an oceanic embayment in the southern margin of the European continent. Driving mechanisms for the Miocene movements of these two intra-Carpathian microplates were the lateral extrusion of the Eastern Alps and the NE- to E-wardretreat of a steeply dipping subduction zone which also caused back-arc extension in the Pannonian Basin. Steepening of the subduction zone started during Oligocene when continental collision in the Alps occurred and slab break-off lead to a halving of the width of the slab. Thus, sideways asthenospheric flow around the edges of the slab reduced the hydrodynamic suction between upper and lower plate, so that the slab started to steepen and to roll back. Due to oblique convergence, collision of the microplates occured first in the N and subsequently migrated towards the SE. Segmentation of the subducted slab enabled the detachment of parts of the slab which were blocked by continental collision. During the last stage, rollback direction changed from E- to SE-ward which is also reflected in the results of seismic tomography showing a deeper N- and a shallower NE-trending slab. Finally, delamination of the lower lithosphere lead to the present position of the slab.

PLATE TECTONICS OF THE WESTERN TETHYAN REGIONS

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The Tethyan realm history recorded the opening and closing of various oceanic domains, mainly a Paleozoic ocean N of the Cimmerian continent(s), the Paleotethys, a younger late Paleozoic-Mesozoic ocean located S of this continent, the Neotethys, and finally a middle Jurassic ocean, the Alpine Tethys, an extension of the central Atlantic, which broke through the Pangea supercontinent. In the western Tethyan regions additional oceanic domains complicate this picture somewhat :
The East Mediterranean ocean, regarded here as opening already in the late Paleozoic is the western extension of the Neotethys;
The Meliata and Karakaya oceans, representing back-arc basins of late Permian age opened in a still active south-east European margin;
The Vardar and Kura-south Caspian back-arc oceans, related to the subduction of Meliata and Neotethys opened during the Jurassic;
The Valais ocean opened between the Briançonnais and S-France during the late Jurassic when Iberia separated from America.
The Apulia-Adria microplate attached to the African plate until early Cretaceous, started a westward displacement as a separate terrane which implies the opening of a Cretaceous ocean, the Arvi-Antalya ocean just north of the old east Mediterranean basin.
Reference: WWW-SST.UNIL.CH

THE SURFACE EFFECTS OF SLAB DETACHMENT: GEOLOGICAL CONSTRAINTS FROM APENNINIC FOREDEEPS

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From seismic tomography it can be inferred that the subducted Adriatic lithosphere has become detached below most of the Apenninic arc. The analysis of the spatial and temporal distribution of Apenninic foredeep depocentres reveals a stepwise, lateral, southeast-directed trend in the development of the Apenninic foredeeps from the Late Miocene onwards. This is interpreted to be caused by the redistribution of slab pull forces associated with lateral migration of slab detachment.
Two areas have been selected for further elaboration. Paleobathymetrical analyses on the Upper Miocene sequence of the Romagnan Apennines (Northern Italy) allowed for the identification of a phase of rebound following depocentre migration. The analysis of the Pleistocene Sant' Arcangelo Basin (Southern Italy) enabled the quantification of subsidence as well as uplift velocities associated with depocentre development and subsequent disruption.

EGS1 Tribute to Stephan Mueller

03 Seismicity and seismotectonics of the Mediterranean region

Convener: Garcia-Fernandez, M.
Co-Conveners: Mayer-Rosa, D.; Panza, G.F.

THE TECTONIC POSITION AND STRUCTURE OF SINAI SUBPLATE, EASTERN MEDITERRANEAN

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The Sinai subplate is separated from Arabian plate on east by the Dead Sea Rift Zone, from African plate on south - by Red Sea Rift Zone. The west boundary with Eastern Mediterranean (Levant) Basin is represented by special historical-structural unit – the Marginal Fold Belt. The thickness of the sedimentary cover on Sinai subplate increases to north from 1-3 km on Sinai Peninsula (Egypt) to 8 - 9 km in Samaria and Galilee (Israel) and decreases to 5 km further north to Levanon. It is possible to distinguish on Sinai Subplate three main platform structural zones from south to north):
1. The Sinai brachisyncline zone is not very intensely dislocated. This zone's northern boundary is the Sinai - Negev shear zone.
2. The Northern Negev machteshim zone of specific discontinuous anticlines (strike - SW - NE, steeper eastern flanks) with Triassic and Jurassic outcrops in axial parts (Makhtesh Ramon, Makhtesh HaGadol, Makhtesh HaQatan).
3. The Central and northern Israel zone of linear folds (main part of Israel) is formed by series of north - northeast linear asymmetrical (steeper western flanks) anticlines and synclines, which continued to north in Levanon. The folds are cut by series of normal, reverse and strike - slip faults. Series of west - east and northwest strike - slip faults, caused mainly by Dead Sea Rift Zone, are especially important. The largest of all the fault zones are the Yizre'el valley and Be'er-Sheva. Author suggests that Israel alpian zone of linear folds (Sinai subplate) is not an extension of Palmyride fold belt (Arabian plate).

LONG-TERM SEISMICITY PATTERNS AROUND ADRIATIC REGION

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According to contrasting points of view, 100 years may be considered as representative of the seismicity of a region and 2000 years may not. In the middle between these views, recent papers have shown that some hundred years can tell much. The current way of looking at seismicity by plotting the whole catalogues is not exhaustive enough to understand the entire process related to the seismic release of a seismogenic zone.
In this paper the analysis of the seismic release is proposed by making use of space and time plots; they help suggesting particular patterns in tectonically different seismic areas of the Adriatic region.

MONITORING THE REGIONAL AND GLOBAL SEISMICITY BY NATIONAL/REGIONAL DATA CENTERS

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In the European-Mediterranean region, a great number of national and regional data centers monitor the seismicity with different goals: such as exact hypocenter location and fault mechanisms, rapid epicenter and magnitude determination or just purely scientific purposes.

This paper reviews the seismicity of Switzerland of the past 25 years, addressing different aspects of data collection and alarm procedures, location accuracy and magnitude thresholds , as well as the exchange of data with surrounding countries for events near the border.

REGIONAL SEISMIC HAZARD ASSESSMENT IN THE EUROPEAN-MEDITERRANEAN: A GSHAP REVIEW

D. Giardini (ETH, Zurich, Switzerland), G. Gruenthal (GFZ, Potsdam, Germany) and the working groups of projects CAUCAS (INTAS CT94-1644), IBERO-MAGHREB, SESAME (IGCP-382), ADRIA, RELEMR (UNESCO/USGS), BEECD (EC CT94-0479) and QSEZ-CIPAR (CIPA CT94-0238)

The assessment of seismic hazard in the EuroMed area has been hindered until now by the existence of national boundaries and by the lack of regional databases, such as a common earthquake catalogue with unified magnitude estimates, and a regional model of source seismic zones. Since 1992 the Global Seismic Hazard Assessment Program (GSHAP), a UN/IDNDR demonstration project launched by ILP, has promoted the regional hazard assessment in different regions and test areas around the world, adopting a uniform seismotectonic probabilistic methodology and compiling, where possible, common regional databases In the EuroMed region, a mosaic of multi-national test areas have been activated, coordinated by the GSHAP regional centers in Potsdam and Moscow and by different projects and agencies: Northern Europe, the Ibero-Maghreb, Caucasus, the Adriatic province, the Balcans, Northern Eurasia, the Middle East. At present the GFZ (Potsdam) is coordinating the integration of the regional results, with the addition of the national maps for Greece and Turkey, in a single map expressing the seismic hazard of the whole Euro-Med expressed in PGA; a summary of the regional results and the preliminary regional map will be presented.

ASSESSMENT OF THE SEISMIC HAZARD IN CYPRUS

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A probabilistic earthquake hazard analysis for Cyprus is carried out using GIS tools for the treatment of data and portrayal of results. A comparative study of the neo-tectonic regime and a critical analysis of historical earthquakes of the Eastern Mediterranean Region obtained from different sources have been made. For recent earthquakes Kandilli Observatory and USGS-PDE Bulletins are used. An artificial homogenisation scheme is used to deal with the non-homogenous character of the seismicity data. For the identification of seismic sources, neo-tectonic features, macro-seismic locations of damaging historic earthquakes and instrumental locations of earthquakes that occurred in the last 50 years are used. The following source zones are delineated: Fethiye, Kyrinea, Levant, Paphos and Hecataeus Ridge. In addition a background seismic zone was defined to account for the floating earthquakes not incorporated in these sources. The probabilistic hazard analysis model used accounts for the variability in the boundaries of these sources. The results are provided as contours maps of iso-peak ground acceleration and iso-spectral acceleration corresponding to different return periods. The results are compared with previous studies of similar nature. The contour maps, provided for 5% damped 0.3 and 1.0s period iso-pseudo acceleration spectral amplitudes with a 10% of probability of exceedance in 50 years, could be used for the rational construction of the site-specific design basis response spectrum.

DETERMINATION OF EARTHQUAKE ENERGY RELEASE IN THE EASTERN MEDITERRANEAN REGION

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We determined the energy radiated from earthquakes in the Eastern Mediterranean Region using the short period recordings of the Israel Seismic Network. Our dataset includes 125 local and regional earthquakes, that occurred during 1990 to 1995 at distances of up to 1500 km, with body-wave magnitude range from 3.0 to 6.2. The released energy is calculated by executing an integration of the squared ground-motion velocity. An empirical attenuation relation of the energy as a function of the distance is obtained. We present the relation between the energy and the seismic moment and estimates of the apparent stress drop.

SEISMICITY AND SEISMOTECTONIC OF THE WESTERN LIGURIAN SEA: A REVIEW

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In the last decade the knowledge and quality of seismological and tectonics data for the western Ligurian Sea has greatly improved. This has been achieved by means of several surveys conducted both off shore and on land together with high reliability seismological data collected from regional and local networks also equipped with high dynamic 3-C seismic stations. On the basis of these new constraints, we performed a broad seismotectonics review using several tools including 3-D relocation, focal mechanisms computation and determination of stress orientation. The results give a new picture of structural setting for this sector of the Ligurian Sea: the seismicity mainly affects the foot of the continental slope in correspondence with some crustal faults. The focal mechanism inversion indicates that whole Western Ligurian continental margin is subjected to a compressive stress component oriented NW-SE. In the center of the Ligurian Sea the seismicity seems to delimit the northern side of the Corsica block. These two seismicity bands outline the existence of the Ligurian sphenocasma. aspects.

THE MAIN FEATURES OF ACTIVE TECTONICS AND SEISMOTECTONICS OF THE CAUCASUS

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(1) The Caucasus as a part of the Alpine-Mediterranean-Himalayan belt is characterised by the high level of seismic activity. That was once more confirmed by such seismic events of the last decade as Spitak, N. Armenia (1988) and Racha, Central Georgia (1991), both of magnitude about 7, taking a toll of thousands of lives and causing an immense social-economic damage. (2) Combined analysis of geological, paleogeological and paleomagnetic data provides evidence that the Caucasus consists of a number of microplates separated from one another by large fault zones with traces of significant both horizontal and vertical displacements. These zones represent belts of maximum geodynamic activity where processes of folding, faulting, volcanism and orogeny are manifested most intensively. These belts also saw the release of a considerable amount of seismic energy. (3) Distribution of earthquakes in the Caucasus reveals their close links with mentioned boundary zones. Three main trends of seismic zones may be distinguished: longitudinal, NW-SE or W-E, and two transversal - NE-SW and NNW-SSE. The first is represented by thrust and reverse faults, while the last two always show more or less considerable strike-slip component. Focal mechanisms of the majority of earthquakes are in good accordance with surface tectonics confirming the genetic closeness between faults and seismisity. (4) Detailed analysis of such important parameters of seismisity as spatial distribution of earthquakes, their focal depth, aftershock activity, focal mechanisms and some others, along with geological data, have permitted judgements of the strained-deformational state of the region and of the nature of the displacement of constituting plates the direct result of which is seismisity.

RECENT/PRESENT TECTONIC PROCESSES IN THE ITALIAN REGION AND THEIR RELATION WITH SEISMIC AND VOLCANIC ACTIVITY

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The attempt at explaining in a physically plausible and coherent way the major post-middle Miocene deformation events in the central-eastern Mediterranean area led us to advance an hypothesis about the driving mechanism and geodynamic processes which have controlled the tectonic activity in this region (Mantovani et al., 1997). The implications of the proposed evolutionary trend on the present deformation pattern are compared with major evidence about the strain/stress field in the Italian region. A discussion is reported about the constraining power of the available strain/stress indicators in the study area. It is then argued that the location and timing of the major Plio-Quaternary magmatic episodes in the Tyrrhenian-Apennines system have been mainly controlled by the occurrence of tensional regimes in the crust, in response to oroclinal bending and lateral escape of crustal wedges.

RELIABILITY OF SEISMIC HAZARD ASSESSMENT IN TERMS OF OBSERVED MACROSEISMIC INTENSITIES IN GREECE

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In areas with long documented seismic history macroseismic intensity, despite all its deficiences, and although it describes ground motion on a very coarse scale, is still the most appropriate parameter for seismic hazard assessment. In the present study, the seismic hazard in a number of urban centers of different seismotectonic characteristics and seismicity rates, in the area of Greece, is estimated, on the basis of observed macroseismic intensities. Local catalogues constructed for each case are used to obtain reliable attenuation relationships which are incorporated in the seismic hazard model. The results of the analysis are verified with real values from strong earthquakes occurred in these regions.

LOW-MAGNITUDE EARTHQUAKES OF ROME: STRUCTURAL INTERPRETATION AND POSSIBLE SEISMOTECTONIC IMPLICATIONS

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Apart from the seismogenic area of Colli Albani Volcanic District, the first instrumental records for the area of Rome are related to two M_D=3.7 earthquakes occurred on June 12, 1995, and November 3, 1997. A common NE orientation of the T axes from focal mechanisms for these earthquakes supports a regional interpretation for the present-day stress-field previously observed in the Colli Albani area, characterised by a NE-striking $\sigma 3$. The structural study has shown evidence of Middle Pleistocene right lateral N-S faulting, implying a NW-striking $\sigma 3$. Since normal faulting linked with NE-SW extensional regime controlled the Plio-Pleistocene evolution of the studied area, it is likely that a combination of different tectonic styles during the last 1 myr should be taken into account. The observed right-lateral displacements is here interpreted as a kinematic surface expression of a major N-S striking crustal discontinuity, corresponding to the southern boundary of the Northern Apennines. The origin and the rejuvenation of the N-S strike-slip faults is interpreted as generated by the north-east escape of the Northern Apennine arc with respect to the Central Apennine.

A DETAILED ANALYSIS OF THE FEBRUARY 1996 AFTERSHOCK SEQUENCE IN EASTERN PYRENEES, FRANCE

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After the February 18,1996, Ml=5.2 earthquake located inside the Agly massif, eastern Pyrenees, France, a temporary network of 26 stations was installed on the epicentre area. A detailed analysis of the aftershock sequence recorded during 5 days following the main shock allows to identify unambiguously the preexisting fault segments in the Agly massif which were involved in the main shock rupture. The focal mechanisms of the aftershocks exhibit a great variety of solutions, but the average orientation of the T-axes determined from all these events has a clear E-W subhorizontal orientation. On the other hand, we determined the fault plane solution and the principal axes of stress using the global inversion developed by Rivera and Cisternas (1990) with the 15 best recorded aftershocks. We obtained a shear rupture tectonic context under N-S subhorizontal compression and E-W subhorizontal extension. These principal axes of stress, which are compatible with at least 75% of the aftershock fault plane solutions of the whole crisis, are compared with the local regional stress before the main shock. In order to integrate the aftershock distribution and the mechanism diversity, we propose a model for the rupture mechanism of the main shock. We calculated the post-earthquake stress field caused by a senestral strike-slip on two vertical fault planes. Most aftershocks concentrate where shear stress increased by more than 0.3 MPa .

SIMULTANEOUS INVERSION FOR VELOCITY STRUCTURE AND HYPOCENTERS IN SLOVENIA

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We use nearly 2100 P-wave arrival times from 166 local earthquakes to investigate the 3-D compressional velocity structure of the upper crust of Slovenia using a simultaneous inversion algorithm which adopts cubic B-splines basis functions for the model parameterization [*Michelini and McEvilly. 1991*]. Remarkable and stable features of the resolved model are the relatively high velocities in western Slovenia and the low velocities in central Slovenia, SE of the Ljubljana basin. The boundary between these two anomalies follows approximately the NNW-SSE direction that coincides with the general strike of the External Dinarides. We interpret this feature as the upper crustal expression caused by the tectonic processes occurring along the active margin of the Adria promontory/microplate.

LESSONS FROM THE PAST: SEISMOGENESIS AND HAZARD IN CENTRAL ITALY

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The earthquake sequence in Central Italy started in September 1997, lead to the re-analysis of the available knowledge for that area. In particular, the seismicity of the past teaches that the actual one is not anomalous as believed. We analysed the seismic histories of the main localities of that area: than we compared the traditional seismic hazard assessment with a simplified evaluation linked to the historical observations. The estimate of the mean return period expected for the different shakings is finally related with the time elapsed from the last event.

MOMENT TENSORS AND SEISMOTECTONICS OF THE MEDITERRANEAN REGION

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Seismic activity provides significant data to understand the kinematics of interacting plates. Focal mechanisms can furnish clear indications of the characters of crustal deformation. We will present inferences on tectonic processes based on the analysis of focal mechanisms of earthquakes of the Mediterranean region. Our database consists of the Harvard CMT Catalog (e.g., Dziewonski et. al., 1981) and from other source moment tensors of smaller and older earthquakes computed with the extension of the standard CMT algorithm proposed by Arvidsson and Ekstrom (1997). Inclusion of smaller-magnitude events contribute to a better understanding of local tectonic structures and their involvement in seismic sequences. Analysis of analog WWSSN seismograms can also increase the time period that can be considered. The robustness of centroid moment tensors is confirmed by the analysis of the extended dataset.

RECONSTRUCTION OF THE MAXIMUM ACCELERATIONS DUE TO THE MAIN SHOCKS OF 1904 SEISMIC EVENTS IN KRESNA ZONE

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Using data for the observed macroseismic intensities the attenuation lows have been derived. The both events occurred on 4-th April 1904 in 10h02min (M=7.2) and 10h23min GMT (M=7.8) created maximum observed intensities of IX and X degree MSK respectively. The McGuire procedure for maximum accelerations mapping has been applied. The soil conditions have been derived in the three main categories due to the surface geological and tectonic conditions. The surface ruptures created by the earthquakes have not been taken into consideration. The integrated picture of the modeled surface distribution of the maximum accelerations have been compared with the descriptions of the macroseismic data observed on different sites. The results show relatively good coincidence between the modeled and the observed destructions for the highest intensities and between the modeled and described feelings and effects for the lower ones. The applied approach must be checked and compare with the different approaches performed by the participants in the ASPELEA Project with EU, to establish the sensitivity of the different approaches.

KRESNA SEISMIC ZONE - A TEST SITE FOR NEW COMPARATIVE APPROACHES

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It is well known that in 1904 in Kresna zone, located now over the border zones of Bulgaria, Greece and Macedonia. two strong shocks occurred on April 4th. They were divided by a time interval of 20 min. and have the estimated macroseismic magnitudes of 7.2 and 7.8 respectively. Due to this fact, the second, stronger shock seems to be the strongest earthquake in the continental part of Europe during the last two centuries. As a result of very complete and nice macroseismic descriptions published in Bulgaria by S. Vatsov, a large amount of data is available now for different comparative studies. For the purposes of ASPELEA Project with EU a very large catalogue of data has been compiled as well as a set of tens of macroseismic maps. In addition the large set of maps for other geophysical fields as well geodetic and fields observations data will be supplied. These data will be processed by the different participants in the project, using different approaches and techniques, as well as the data from other test sites, to compare the sensitivity of the different approaches for seismic potential assessment of large seismic areas in Europe. The results obtained will be useful for the scientific community as well as for the local authorities for the prevention and restoration works in furure.

A NEW CATALOGUE OF DIGITIZED HISTORICAL SEISMOGRAMS FOR IBERIAN EARTHQUAKES

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The bulletins and seismograms accumulated since the beginning of instrumental registration in the Geophysical Observatory of Toledo (Spain) up to the time of installation of WWSSN station (1912-1962) have been revised. A total of 244 regional earthquakes recorded by the Wiechert seismograph were collected, digitally recovered and properly processed. The final results of the geometrically corrected records and the time variations of the ground displacement for each seismographic component, as well as the main principles of the digital recuperation and treatment, are presented in a *Catalogue of Historical Seismograms*. This new digital database was used for creation of a unified magnitude system for classification of the historical earthquakes in the region of Iberian Peninsula. The existent earthquake catalogue was revised and magnitude corrections were suggested.

DIFFERENT ASPECTS AND CONSIDERATIONS ON SEISMIC HAZARD IN THE ADRIATIC REGION

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Countries surrounding the Adriatic sea are highly exposed to seismic risk. Due to its seismological interest, and to the transfrontier character, the Adria region has been selected as a test area in the frame of the GSHAP (Global Seismic Hazard Assessment Project) activities; and the probabilistic seismic hazard evaluation in term of peak ground acceleration (PGA) has been performed.
The probabilistic assessment benefits of three favourable factors:
a) the joint kinematic modelling of the seismogenic sources in Italy and Balkans; b) the compilation of an hazard oriented European catalogue (prepared in the frame of the EC Project "A Basic European Earthquake Catalogue and Database"); c) the experience matured in Italy with the compilation of the new hazard maps according to EC8 for the revision of the seismic zonation.
Seismic hazard in terms of spectral amplitude at two different periods (0.2 and 1 sec) has been evaluated for the Adriatic region, and the uniform hazard spectra for some sites of interest have been computed. In this way the contribution of the characteristic seismicity of close and far sources remains pointed out.

A NEW, ACCURATE MAP OF THE PYRENEAN SEISMICITY AND ITS TECTONIC IMPLICATIONS

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A new seismicity map covering the whole Pyrenean range has been obtained from a compilation and reprocessing of published P and S arrival times. The data come from 8 bulletins produced by the various French an Spanish institutions in charge of the seismic survey of the range. The map concerns the last 9 years starting 1989, when the range has been homogeneously instrumented. Hypocenters have been determined for about 400 events per year. A particular attention has been paid to the evaluation of the quality of the locations and depth determinations. Magnitudes have been re-evaluated. The comparison with previous maps reveals significant improvements in both the quality of locations (generally better than 3 km in both horizontal and vertical positions) and the threshold of detection (Ml~2.0). This new map reveals that the North Pyrenean fault, which is considered as the plate boundary between Iberia and Eurasia, is active only in its western part. In the central and eastern parts, the seismicity involves other tectonic units such as the Maladeta and Canigou granitic massifs, the North Pyrenean Frontal Thrust, the Tet fault and the volcanic units in Catalonia. A period of recurrence of 150 ± 40 years for a magnitude 6 event is deduced from the Gutenberg and Richter relationship, it is consistent with the records of historical seismicity. This new map appears as a valuable tool for future tectonic studies.

QUANTITATIVE SEISMIC ZONING IN THE MEDITERRANEAN AREA

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We show the joint results of the deterministic seismic hazard assessment obtained in the framework of a large international cooperation (supported by EU-INCO COPERNICUS, NATO and UNESCO-IGCP). Countries involved are: Algeria, Bulgaria, Croatia, Hungary, Italy, Romania and Slovenia. Characteristic parameters of seismogenic zones and regional structural models have been assembled and synthetic seismograms have been computed for a dense grid of sites covering the whole territory. Particular attention has been paid, in order to obtain a homogeneous definition of the input data across political boundaries. This is a crucial point in order to produce coherent hazard maps for large regions with many countries. Results are shown in terms of maximum displacement, velocities and Design Ground Acceleration.

SEISMIC STRAIN RATE ESTIMATES IN THE CENTRAL - EASTERN MEDITERRANEAN REGION: A RELIABILITY ANALYSIS

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Deformation accomModated by seismic faulting can be used to constrain active tectonics in the central-eastern Mediterranean area. To this purpose, fault plane solutions available in the relevant literature have been analyzed. A preliminar zonation of the area has been performed on the basis of geological and geophysical considerations in order to identify those areas characterized by nearly uniform expected strain field. Then, for each area, strain rate tensors have been computed as the sum of seismic moment tensors associated to each earthquake (Kostrov's approach). Scale invariance and confidence intervals associated to principal strain directions have been tentatively estimated. Since the parent probability distributions of experimental uncertainties which affect fault plane solutions are poorly known, confidence intervals have been computed by following a distribution-free approach based on a numerical resampling procedure (Bootstrap). In this way, the preliminar zonation have been revised and those areas where a reliable strain rate estimate is acually possible have been selected.

EGS2 Geophysical and geological signatures of past and present climate change

Convener: Premoli-Silva, I.
Co-Conveners: Herbert, T.D.; Maley, J.

LAST MILLENNIUM CLIMATE HISTORY INFERRED FROM BOREHOLE TEMPERATURE PROFILES: REGIONAL PATTERNS OF CLIMATIC CHANGES IN THE CZECH REPUBLIC

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Borehole temperature logs after their inversion may be certain indicators of the ground surface temperature (GST) variations associated with the climate changes in the past. Ninety eight such GST histories described by authors in their previous works were used in an attempt to assess the regional patterns of the climate changes in several selected periods: 1100-1300 A.D. (Little Climatic Optimum), 1400-1500 A.D. and 1600-1700 A.D. (Little Ice Age), completed by "mapping" of the recent climate warming since 1960. Comparison of the obtained results with the meteorological observations and proxy climatic reconstructions confirms the general applicability of the "geothermal" paleoclimatic reconstructions even for the regional studies.

PRIMARY PRODUCTION DYNAMICS IN THE EQUATORIAL INDIAN OCEAN : SOUTHERN OSCILLATION AND/OR MONSOON ORIGINS

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Analysis of continuous sedimentary records taken in the Maldives and the Somalian areas indicate that strong primary production (PP) fluctuations have occured in the equatorial Indian Ocean during the last glacial cycles. The PP record from the Maldives which is 910 kyr long, is coherent and in phase with the February equatorial insolation, whereas it shows diverse phase behavior with δ18O, depending on the orbital frequency examined. These observations imply a direct control of PP in the equatorial oceanic system by insolation. Maldives PP variations are in opposite phase with summer monsoon variability and are due to the dynamics of the Indian Equatorial Westerlies, which are in turn dependant on the Southern Oscillation. The two PP records from the Somalian area present a complex signature which is alternatively in phase with the Maldives record and with the summer monsoon. These findings have implications on (1) the regional climatic responses to Southern Oscillation and Monsoon (2) the independance of the tropical climates from high latitudes (3) the existance of 100-kyr not related to ice volume variations.

COMPARISSON OF GEOTHERMAL GROUND SURFACE TEMPERATURE HISTORY WITH INSTRUMENTAL AIR TEMPERATURE SERIES IN MAINLAND PORTUGAL

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The ground surface temperature histories were reconstructed from 20 borehole temperature logs measured in mainland Portugal. We used the functional space inversion method, which employs the theory of heat conduction in a laterally homogeneous Earth and incorporates a priori information to stabilize and uniquely determine the solution. The topography in boreholes' surroundings is subdued and the logs do not indicate water disturbance. To avoid the reconstruction of spurious ground surface temperature variations from non-climatic features of the inverted profiles, we carried out the inversions for two different sets of a priori model standard deviations. Beside the standard deviations 0.5 W/m.K for the thermal conductivity and 0.04K for the measured temperature, which represent the typical degree of uncertainty in these data, we also used values 2 W/m.K and 0.1 K, respectively. These higher values prevent inverting noise as a climatic signal by absorbing it in a posteriori conductivity and temperature profiles. Most of the inversions reveal warming in the last 100-150 years, which is consistent with meteorological observations. Some of the reconstructed histories show a slight cooling in the second half of this century. Similar cooling can be observed in the air temperature record from Lisbon.

NEW OCEANOGRAPHIC DATA AND HEAT FLOW MEASUREMENTS IN THE SEDIMENT KEEP TRACK OF THE ACTUAL CLIMATE CHANGE IN THE EASTERN MEDITERRANEAN

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During the first cruise of the SINAPSI Project (Seasonal INterannual and decAdal variability of the atmosPhere, oceanS and related marIne ecosystems) onboard R/V Urania (Nov.-Dec. 1997), twelve CTD profiles in the water column and 51 new conventional heat flow density measurements in the sediment were carried out in the Jonian Sea, along a 600 km long corridor at about 36° N, from the Malta Escarpment, to the west, to the Matapan Trench, to the east. The main target was to track the recent outflow of warm and dense deep waters propagating westwards from the Aegean Sea, and the associated sediment warming discovered in September 1993 during the 15/93 Urania cruise. The new observations in the Matapan trench near-source area showed a persistent positive temperature anomaly at the seafloor, exceptionally well documented in the sediment thermal history. The propagation of warm and dense Aegean waters could be met again up to the crest of the Mediterranean ridge (about 200 km to the west), which seems to behave as an effective water divider for the deep circulation. The influence of such a large scale process seems to have not yet reached the central and western portion of the Jonian Sea. Space and time constraints for this climate variability event will be presented.

CAN WE USE SEDIMENTARY RECORDS TO DEDUCE LONG-TERM CHANGES IN THE EARTH'S ORBITAL ECCENTRICITY?

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Geologists have made detailed comparisons betwen climatic time series and orbital forcing on time scales of 0-8 Ma. Generally, geologists use the orbital calculations to assign ages to paleoclimatic events. However, the orbit-sediment comparison need not be one-way. Lourens and colleagues argue that early Pliocene-late Miocene sedimentary records from the Mediterranean region favor a particular orbital solution from Laskar over competing solutions. We assess here the stability and accuracy of long-term integrations of the earth's orbital eccentricity around the Sun in comparison to marine records of late Cretaceous (ca. 84 Ma) to middle Paleocene (ca. 60 Ma) age, dated and correlated by high-resolution magnetics. We trace the eccentricity cycle by its modulation of carbonate maxima and minima driven by precessional insolation cycles (mean observed period = 20.9 k.y. vs. expected 20.4 k.y.). Robust modulations occur at 100, 400, and 2400 k.y. The last two periods are long enough, relative to errors in geological time scales, to compare to predictions from celestial mechanics. We find that 1) the major periods of the eccentricity series have been stable since the late Cretaceous, but that 2) the dates obtained for maxima and minima of the 2400 k.y. period differ from simple extrapolation of orbital calculations performed for the last 10 Ma.

ANTARCTIC ORIGIN OF THE FIRST GLOBAL MELTWATER PULSE FOLLOWING THE LAST GLACIAL MAXIMUM

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The origin of the global meltwater pulses following the Last Glacial Maximum (LGM) is still under discussion. Sea level records show, that the rise following the LGM was characterized by two or three brief intervals of rapid sea level rise separated by periods with much lower rates. A freshwater input into the North Atlantic equivalent to two or three times the Greenland ice volume within less than 500 years is assumed for the meltwater pulse 1A around 14 kaBP. We present first evidence of massive calving of the Antarctic Ice Sheet during the last deglaciation confirming the hypothesis of Clark et al. (1996). The correlation of high-resolution magnetic susceptibility records of Scotia Sea sediment cores with the dust concentration of the Vostok ice core provides a high resolution chronology. Records of ice rafted debris (IRD) from the Scotia Sea show exceptionally high fluxes of IRD during the last deglaciation, striking features are two IRD pulses between 10 and 14.5kaBP. Calving starts after the onset of the drastic warming observed at Vostok around 15kaBP and seems to culminate during the so-called Antarctic Cold Reversal at 13-14kaBP. We assume that increasing temperature and sea level (due to melting ice in the northern hemisphere) caused first the ice shelves to break off and, at a later stage, parts of the grounded Filchner-Ronne and Ross Ice Shelves to collapse. The melting icebergs significantly cooled the Southern Ocean and lead the Antarctic Cold Reversal, seen in the temperature during the deglaciation.

SUBSURFACE TEMPERATURE SIGNALS IN MOUNTAIN AREA

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Recently, the evaluation of thermal effects at shallower and deeper underground aims at identifying former structural or climatic situations. Temperature is thus treated more and more as archive which contains information on the past. For the analysing archives of the past ~10^4 years the inversion of temperature logs provides strong hints to a change in ground surface temperature and thus to the palaeoclimatic conditions in. the considered period. Impacts of such analysis encountered in mountain area will be investigated. The numerical calculations by the finite element method takes into account complex topography, fluid advection as well as uplift and erosion. The results highlight especially that even complex topography combined with fluid advection will not extinguish the palaeoclimatic temperature signal. Strategies are presented which allow to extract information even from strongly perturbed temperature logs. In contrast, the temperature information extracted from fluid inclusion data is strongly perturbed by advection of masses (uplift and erosion). We will illustrate these effects on examples which are characteristical for moderate and high topographies. The temperature signals at the well investigated area of the KTB borehole offering the unique possibility to combine information from different geoscientific fields and also the possible extreme conditions of an Alpine – type mountain belt which may strongly perturb thermal field will best illustrate impacts on the palaeoclimatic temperature signals in subsurface.

ROCK MAGNETIC SIGNATURE OF MILANKOVITCH CYCLICITY RECORDED IN MID-CRETACEOUS HEMIPELAGIC SEDIMENTS OF THE VOCONTIAN BASIN (SE FRANCE)

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A rock magnetic study of Mid-Cretaceous hemipelagic sediments has been carried out in order to identify paleoclimatic cycles driven by changes in the Earth's orbit ("Milankovitch cycles"). Calibration of cyclic behaviour of magnetic properties could provide a powerful tool for sedimentary chronometry. The observed Aptian succession of marls and claystones with intercalated black shales and marly limestones shows a cyclic pattern of variations in magnetic susceptibility. Constant values of isothermal remanent magnetisation (IRM) ratios indicate a constant content of ferrimagnetic minerals and thus continuous sedimentation without clastic components delivered from secondary sources. The curves of saturation IRM (SIRM), that is sensitive to ferrimagnetic minerals, do not correspond to the susceptibility so that the susceptibility signal is dominated by fluctuations of the paramagnetic mineral content. While the frequencies of susceptibility variations express the precessional and eccentrical cycles, the SIRM reflects the obliquity of the earths orbit. Our results demonstrate the suitability of rock magnetic parameters to identify and interprete climatic cycles even in Mesozoic successions.

RECONSTRUCTION OF THE PALEOCLIMATE OF NORTH BULGARIA DURING THE PLEISTOCENE AND HOLOCENE

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The paleoclimate reconstruction problem consists in determining the earth surface temperature in the past. Such a problem is easily reduced to equivalent Fredholm integral equation from the first kind with help of the Green function. When solving the above problem there are mainly two difficulties: 1) Constructing an effective algorithm for calculating the Green function determining the kernel of the integral equation; 2) Getting to a stable solution of the integral equation of the first kind, representing a ill-posed problem. In order to calculate the Green function we use its presentation to Fourier integral transformation with separating the subintegral function peculiarity. When solving the integral equation from first kind we use the Tikhonov's method of regularization in which the smoothing functional is minimized. The temperature profile obtained from borehole P-117 in North Bulgaria was investigated to extract information on paleoclimate variations during the last Pleisticene and Holocene. The first more noticeable warming began 14000 years ago. After a short cooling the so-called holocene warming began. Lasting increase of the average yearly temperature could be observed. It reached its maximum during an interval of 7000-6000 years.

SEA LEVEL CHANGES IN THE NEAR FUTURE

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Sea level can only change within the limits set by the physical processes involved. Sea level changes is a multi-facetted problem, however, that calls for deep knowledge in a number of different subjects and interacting processes. This is especially true when it concerns the changes during the last centuries and the expected future changes. Tectonic changes of the volume of the oceanic basins are too slow to have any significant short-term impact. Glacial eustatic changes virtually finished in Mid-Holocene time. The steric expansion of the water column is limited to the surface layer of the oceans. The gravity potential surface (the geoid) constantly deforms. The most powerful process of rapid changes in regional sea level refers to the variability in the main oceanic circulation system as a function of interchange of angular momentum between the solid Earth and the hydrosphere. If global sea level has risen in the last 150 years, it can never have been more than by 1.1 mm/yr. This rate – about 10 cm per 100 years – is a good approximation of the maximum sea level rise even for the future. A possible global warming will not change this significantly. Therefore, the estimated changes in sea level in the near future must be: "some 10 cm – at the most 20 cm – per century".

NEOTECTONICS AND GLOBAL CLIMATE

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It recently became evident that the globe experienced a significantly changed tectonic regiment from about 3.0 Ma onwards. Large areas were rapidly uplifted between 3.0 and 2.5 Ma (e.g. the Tibetan Plateau, large parts of the Cordilleras, the Ethiopean and SE African Plateaus, parts of Europe, maybe the Transantarctic Mountains). Other areas subsided (e.g. the Bajkal, Caspean, Tyrrhenian and North Sea Basins). The Bransfield and Bering Straits opened. The African plate-push was intensified. Large parts of the deep-sea floor seem to have subsided (in hypsographic adjastment to the land-uplift). We are hence able to identify the last 3 Ma as characterized by generally intensified tectonic activity of such dimensions that we have to go very far back in time to find anything similar. This period may hence be looked upon as a special "neotectonic period" putting the term "neotectonics" in new perspectives. This tectonic reorganization seems - by amplifying the Milankovitch variables - to be causally connected to the alternations between ice ages and interglacials that set the character of the climate for the last 2.5 Ma.

EARTH'S ROTATIONAL RESPONSE TO THE LATE-PLEISTOCENE GLACIAL CYCLE AND TO CURRENT GLOBAL CHANGE

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Several "anomalies" in the Earth's current rotational state have been interpreted as aspects of the planet's response to the 100 kyr cycle of late Pleistocene glaciation and deglaciation that has characterized the most recent 900,000 years of earth history. As first demonstrated in Peltier (1988, Science, 240) these anomalies, which consist of the non-tidal acceleration of axial rotation and the speed and direction of true polar wander, are also extremely sensitive to the occurrence of any significant degree of present day melting of land ice, either in the form of small ice-sheets and glaciers or of large polar ice-sheets such as those that presently cover Greenland and Antarctica. I will describe a series of analyses that have been performed in an attempt to discover what constraint, if any, the observed data may be invoked to place upon the amount of polar ice sheet melting that may presently be contributing to the ongoing modern rise of sea level that appears to be occurring at a globally averaged rate near 1.8 mm per year. These analyses strongly suggest that any such contribution must be small, especially from Antarctica, and therefore that the contribution to the modern global rate of sea level rise from the steric effect of thermal expansion must be much larger than conventionally assumed.

CONNECTION BETWEEN THE CHANGES OF GEOMAGNETIC FIELD INTENSITY AND CLIMATE CHANGES IN THE HOLOCENE.

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The connection between geomagnetic dipole value M/Mo (Mo- modern value of geomagnetic dipole) change and surface temperature variations for the last 12,000 years was analysed. The changes of geomagnetic dipole was traced by the way of paleoarchaeological data (up to 8000 BP) and sediments data generalization (from 8000 to 12,000 BP). As the climate trend were used temperature dependences on core data both in Northern and Southern hemispheres and as well on the analysis of palinological data and glacier development. Curve of connection between M/Mo changes and temperature T ones demonstrate practically linear dependence under M less than 0.5-0.6 Mo. In the case increase of M corresponds to surface temperature increase. Under further growth of M, above mentioned dependence begins to weaken and at M equal or more than Mo increase of temperatures is practically stopped. T(M) curve obtained taking into account its configuration looks like the curve of cosmic ray intensity changes in the atmosphere under geomagnetic field intensity changes. Taking into consideration the conclusions concerning cosmic ray action modulated by solar activity on the optical properties and radiation balance in the atmosphere one can make an inference that connection between surface temperatures and geomagnetic field changes in Holocene have got physical nature.

MULTIFRACTAL ANALYSIS OF ICE CORE CLIMATE DATA

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Ice core climatic records such as those of the Greenland Ice-core Project (GRIP) are very usefull to characterize the climate system for large time scales. The GRIP data already showed that climate proxy temperatures ($^{18}O/^{16}O$ ratios) display sharp gradients and large fluctuations over all observed scales. We show that these variations are scaling over the range ≈400 yr to ≈40 kyr: there is no characteristic scale, and the fluctuations from one scale to another depend only on the scale ratio. The fluctuations corresponding to these scales are studied using multifractal analysis techniques. The entire hierarchy of multifractal exponents characterizing the climate statistics over this range is found to fit very accurately in the framework of universal multifractals. This means that many of the details of the complex climate dynamics are "washed out", leaving only statistically multifractal fluctuations at all scales.

One of the consequences of this data analysis is that modelling what is usually called "natural climate variability" using Gaussian noise or random walk leads to strongly underestimate the variability. Indeed the latters are additive processes whereas multifractals correspond to multiplicative processes, displaying long-range correlations.

STRATIGRAPHIC SIGNATURE OF TERTIARY CLIMATE CHANGE ON WEST AFRICAN MARGINS

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The post-rift sequence of the west African continental margins comprises 1) an Aptian-late Eocene interval dominated by aggradation on a carbonate ramp; 2) a major unconformity corresponding to an erosional hiatus of the L. Eocene-E.Oligocene on the shelf-edge; and 3) an Oligocene to Present interval characterised by progradation of terrigenous sediments across the shelf and sediment-drifts accumulation in the slope.

Such first-order stratigraphic organisation has been attributed to uplift of Africa, however geological evidence indicates that uplift was a multi-stage process spanning the whole Tertiary, which is not in agreement with the observed E. Oligocene stratigraphic turnover.

Comparison of the stratigraphic record of the West African margins with $\delta^{18}O$ and $^{87}Sr/^{86}Sr$ curves shows a close temporal relationship with Tertiary climate degradation and increased continental weathering. Changes in morphology and sedimentary pattern of continental margins are correlated with the first occurrence of Antarctica glaciations in the earliest Oligocene. Development of "icehouse" condition from Oligocene onwards, introduced seasonality and long-term lowering of the sea-level, which favored continental erosion and increased clastic supply to the margins, while the contemporaneous establishment of thermohaline circulation correlates with the onset of sediment-drift deposition on the continental margin.

MONITORING CLIMATE CHANGE IN THE EARTH'S SUBSURFACE

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Past ground surface temperature changes, which are preserved in the earth subsurface, can be recovered from borehole temperature data. Whereas a single hole measurement represents a snap-shot of the transient thermal state, continuous measurement of temperature at different depths is needed to obtain complete information on evolution of temperature field and hence on mechanisms governing heat transfer in the first tens of metres below surface.
We set up an observatory in a hole drilled in south Bohemia to measure temperature from the surface down to 40 m depth together with standard meteorological variables and soil moisture. The aim is to monitor energy and mass fluxes in atmospheric boundary layer, in soil and in the basement rock. The observatory setting (including 3-D model of relief effect on temperature) and the first data analysis is presented.

HOLOCENE VEGETATION, LAKE LEVEL AND CLIMATE CHANGE IN MONGOLIA: A RESPONCE TO THE INSOLATION FORCING

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Vegetation records from forest/steppe transition, highly sensitive to changes in precipitation and temperature regimes, are the key to examine the response to millennial-scale change in the regional climates. These are mainly controlled by the orbitally-induced global pattern of insolation through changes in temperature and atmospheric circulation. For the first time we present a continuous record of vegetation and climate change from Hoton-Nur Lake, northwest Mongolia since 11,000 cal. yr BP (ca 10,000 ^{14}C yr BP). Pollen data suggest steppe covered the area at 11,000-10,000 yr BP. Lake was low. That is consistent with dry climate, associated with weaker than present Pacific monsoon. *Picea* dominated forests became very important already at 9.5 kyr, suggesting wetter than present conditions, in response to the expanded monsoon. High and intermediate lake levels reconstructed at that time are consistent with such interpretation. A sharp reduction of *Picea* and re-establishment of steppe with sparse patchy forests occurred after 5000 yr BP, consisting with attenuation of the monsoon activity in the region. A decrease in the lake level is parallel to the change in vegetation. A human impact in the region is unimportant until today, suggesting reconstructed patterns reflect climate change primarily driven by insolation changes.

EGS3 Modelling techniques and joint inversion in Earth sciences

Convener: Götze, H.-J.
Co-Conveners: Meurers, B.; Romanyuk, T.V.; Schmidt, S.; Strykowski, G.

SOME NUMERICAL APPROACHES TO SOLVING THE INVERSE PROBLEMS OF ELECTROMAGNETOELASTICITY

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New numerical methods for solution of inverse problems for electromagneto-elasticity equations are proposed. The Maxwell and Lamé systems are considered in the case when the electromagnetic (EM) field is generated by elastic oscillations. We neglect the reverse influence of the EM field on the elastic oscillations. When elastic waves propagate through an electroconductive medium within the magnetic field, an interaction between EM and elastic oscillations appears. The resulting waves are called EM-elastic waves. The influence of the EM field on the deformation field is considered as a result of the Lorentz forces. To account for an increase of the electric field density, an additional term should be included into the equation describing the Ohm law. This term depends on the velocity of particles which move in the magnetic field. In our case the influence of the magneto-elastic field on the elastic waves propagation is negligible. At the same time, if the original magnetic field is strong enough, the influence of the magneto-elastic forces can be significant. We consider the problem of recovering some elastic and EM parameters of a layered medium from a weakly coupled linearized set of equations of electromagnetoelasticity. Results of numerical experiments are given. (The research was supported by RFBR under grants 96-05-66058, 95-05-15567.)

GRAVIMETRIC MODELLINGS OF THE SOUTHERN ANDES (38:-42:S)

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Gravimetric investigations were carried out in 1995 and 1996 in the Southern Central Andes (38:-42:S latitude and 72:-74:W longitude), as part of an interntional attempt to reveal structural information of the Andean lithosphere. As a result of the field investigation (12500 stations) we prepared maps of the Bouguer, isostatic residual anomaly and gravity lineaments obtained from horizontal gradient. An interpretation of the processed gravity data indicates the geological framework of the Southamerican subduction zone beneath the Andes. -The Coast Range fundamentally composed of metamorphic rocks of paleozoic age, shows in general negative anomalies between 0 and -30 mgals.-The Central Valley covered with 2000 to 4000 meter of Quaternary sediments, showspositive anomalies between 10 to 100 mgals., the largest positive anomalies encountered in the region under study. The cause of these anomalies over a sedimentary basin is probably the existence of hight density upper mantle material under an abnormally thin crust . These positive residual anomalies are the desappear south of 38.5:S. -The area comprising the Pre-Cordillera and the Pre-Andean Basin composed of Quaternary sediments and volcanic rock, shows low residual anomalie, in a SE lineament that starts at the Arauco Peninsula, 37:S at 39.5:S. The anomalie takes a NS trend along the west side of the lakes of the region.-Finally the volcanic belt of the western-cordillera does not show a clear pattern judging from the isostatic gravity residual. That are characterized here by a sequence of high and low values.This projet was financed by the Volkswagen Fundation, Germany.

DENSITY STRUCTURE OF THE NORTHEAST GERMAN BASIN: 3D MODELLING ALONG THE DEKORP NE-PROFILE.

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The key of understanding the dynamics of the Northeast German sedimentary basin is the knowledge about its current structures. Our studies will focus on the evolution and subsidence history of this basin by the aid of numerical models. Therefore it is necessary to consider all geoscientific information and data which are available to support this task. Due to the complex basin geometry and evolution we will concentrate our modelling on some sub-areas. The principal idea behind this paper is to show the state of data acquisition and recent results of 3D-modelling. At first the layers of the basin structures were compiled on the base of borehole data, two seismic profiles and isostatic modelling. Gravity, aeromagnetic and geoidal maps completed the data base. By means of 3D gravity and geoid modelling, the initial model structure was modified to fit in the geophysical data sets. The gravity effects of salt domes and walls concerned with the mobilisation of salt layers, cause strong negative anomalies of gravity. Another problem is related with the construction of the 3D model's Moho interface. Here, the modelling benefits from the first results of the seismic reflection studies along the DEKORP NE profile. Aeromagnetic modelling was done together with density modelling in one program step and help to identify areas, where the volcanic rocks of reasonable thickness exist. The anomalies of the gravity field are interpreted in terms of crustal distributions of density against the first findings of the seismic reflection experiments.

PART OF THE NEW CONCERT FOR OIL FORMATION IN SCIENTIFIC INFORMATIONAL MODELS

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A process of geological and geophysical investigations is a simulation process on a basis of sciences interconnections. Synthesis of scientific knowledge and practical skills enables to construct model of a natural object as one of the form for visual representation of a geological object.

Depending on complexity of the solving problems, a set of informational data for their solution differs.

From our point of view, proper understanding of oil origin allows to partially or completely solve the problems of three distinguished levels: global, regional and particular. Namely, formation of gas hydrates, hydraulic fracture of the seam, lowohmic productive reservoirs, tectonic motion, facies analysis, anomalous formational pressure and others.

FIRST STEPS TOWARDS AN INTEROPERABLE 3D GIS – AN EXAMPLE FROM SOUTHERN LOWER SAXONY, GERMANY

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In geosciences the necessity of combining geological and geophysical information as well as applying tools for designing 3D models is well accepted. Nevertheless, in most cases this demand is only put into practice by file transfer between the applications. Therefore the creation of a 3D model is aggravated by the inflexibility for handling additional or re-interpreted data and for the treatment of changing applications, operation systems and/or platforms. To improve the first aspect, an object oriented database system (OODB) is developed, wherein the original data as well as the derived data and the 3D models are stored. Geo-applications have direct access to the OODB by utilizing the technology of common object request broker architecture (CORBA). Hereby integration of the software components and independence from both changing software applications and changing platforms are obtained, finally resulting in an InterOperable 3D GIS (IOGIS).

We present an example of the exchange of spatial objects between a geological and a geophysical software application using CORBA's interface definition language (IDL) as an integrated approach of geological and geophysical 3D modeling in southern Lower Saxony.

LITHOSPHERE STRUCTURE OF THE SEDIMENTARY BASINS IN THE CARPATHO-PANNONIAN REGION AS INFERRED FROM INTERPRETATION OF GEOPHYSICAL DATA

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The Carpathians and the Pannonian basin system provide a good opportunity to study extensional tectonics. The Danube basin and the Békés basin are a Neogene-Quaternary basin complexes, which belong to one of the largest Neogene depocentres in the Carpathian-Pannonian region. Presented lithospheric model of the slovak part of the Danube basin is inferred from the regional deep and local reflection seismic profiles, gravimetric and magnetic data, crustal and lithospheric thickness maps, a Royden's thin-skinned lithospheric model of the Vienna basin and new facts on its geological structure. For the Békés basin local isostatic model, 2D gravity model of the lithosphere, 3D gravity effect of the basin sedimentary fill and the stripped gravity map were calculated. To contribute to better understanding of the process of the continental extensional tectonics the first attempt to solve of the state of stress associated with the narrow continental rift mode was done. For calculation of the state of stress in the 2D model the finite element method was applied.

MODELLING OF GRAVITY AND MAGNETIC FIELDS NEAR URSEIS-95 PROFILE AT THE SOUTHERN URALS.

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The interpretation of gravity and magnetic data were carried out on a number of profiles located on the Southern Urals in the region of URSEIS-95 seismic profile, and alternative variants of cross-sections were constructed. Results of gravity field modelling indicate that positive anomaly over Magnitogorsk zone is cause by heavy rock blocks in upper 10 -15 km layer. Negative regional gravity anomaly at the Southern Urals may be explaine by uralide complexes with lower density at the bottom of the crust and increasing of the crust thickness to 45-50 km. From the results of the magnetic data an extensive negative magnetic anomaly was identified under the main Ural structures. We explained the nature of this anomaly by the contrast in magnetization between crystalline basement of the platform and uralides and sinking of Precambrian platform's basement under the orogen. At the western part of the profile the number of lingering sources are correleted well with seismic boundaries in the lower horizonts of East-European platform.

GENERATION OF GEOLOGICAL MAPS BY AN INTEROPERABLE APPROACH – AN EXAMPLE FROM SOUTHERN LOWER SAXONY, GERMANY

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Geological maps constructed in a conventional way may have deficiencies for several reasons: The editor might not be able to integrate all available information into the 3D model, there might be no possibility to control all aspects of consistency and plausibility of the 3D model because of its geometric complexity and/or, finally, the exploration of all spatial consequences within the 3D model is a tedious task. We present an interdisciplinary approach of computer scientists, geophysicists and geologists to implement an integrated application of an object oriented database system (OODB) and geological and potential field 3D modeling software. Spatial distribution and heterogeneity of the platforms used requires the deployment of Object Management Architecture (OMA). Thereby the utilized software tools become compliant to Object Request Broker (ORB) technology and the geoscientific 3D modeling software will get direct access to the OODB. The study area is located in southern Lower Saxony, Germany. A high density of well information, several isosurface maps, and a great number of geophysical surveys combined with the iterative exchange of the 3D geometry between geological and geophysical modeling tools leads towards the construction of a consistent 3D model.

THE MODELLING TECHNIQUES FOR STUDYING THE PROPERTIES OF GEOPHYSICAL FIELDS IN SINGULAR AREAS

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Solving of the stationary problems connected to 3D mathematical modeling the situations appear when field components are increasing infinitely close to the edges, angular points and singular areas. It has been noted early the necessity to concern such areas in the edge areas of gravity anomalies similar to singular areas (Gridin and Gak, 1994, Gak et al, 1997]. It has been noted that those zones might have the increased normal component module, and the GF horizontal components. However, the difficulties of mathematical description of such phenomena, underestimation of the role of the tangential component particularly in case of gravitational fields makes prospective the application of the methods of laboratory simulation not only for the structure of such zones, but also for phenomena talking place inside. This work describes the methods of generation of the fringe effects of electrical, magnetic, and gravity fields in laboratory conditions, as well as simulation of the phenomena of mass and electric transfer in above zones. The comparison of obtained results with the data obtained in field conditions and at remote sensing are presented. The authors consider that it is necessary to take into consideration the role of such zones on the Earth's surface in coarse of studies of evolution processes of living systems and the nature of influence of cosmic factors, the gravity fields of the Sun, the Moon and other heavy planets, cosmic substance (cosmic dust and cosmic rays) among others. In the same time the progressive studies of such phenomena, possibility of their practical application both in geological survey and for the prediction of catastrophic natural phenomena may be successfully implemented only at the collaborated participation of the experts of different profile in these works.

APERIODIC MOTION OF A CRUSTAL MICROPLATE WITH APPLICATION TO MOESIAN PLATFORM - ROMANIA

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An analytical formula is derived for the flexure of the 1-D plate in presence of a horizontal compressive stress. The load is approximated by a sum of arbitrary step functions. On that base, a quasi finite element algorithm is obtained for static crust modelling. By incorporating gravity, seismic, seismological and well-logging data, the code is applied to the Moesian Platform (MP), a microplate mainly bounded by the Carpathians, Balkan Mountains and North Sea. It is concluded that the actual load is insufficient to keep the microplate into an equilibrium state. Assuming that Bernoulli hypothesis is valid for all time, a differential equation is derived for the time-variable flexure by generalising the Sophie Germain result. It is used to obtain the periods of the normal modes of a rectangular plate laying on a viscous substratum and the corresponding critical values of viscosity η. For the MP microplate, the lowest mode has 534 seconds and η is 8x10**11 Pa sec, indicating that, most probable, the motion is strongly damped as excited by an earthquake. The aperiodic motion is discussed in detail. From the recent vertical movements in the area, the derived mean viscosity below Moho discontinuity is 7.4 x 10**22 Pa sec corresponding to a strain rate of 8 x 10**-16 sec**-1. Sphericity effects are rigorously investigated. For MP microplate, with horizontal sides of the order 600 x 240 and thickness of 24 kilometres, the curvature of the Earth can be ignored.

Concept and examples of interactive visualization with IVIS-3D

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This poster outlines the concept and visualization capabilities of IVIS-3D (IGMAS **Visualization** in **3D**), which is an interactive 3D-visualization program. This tool is specially adapted to the requirements of gravity and magnetic modeling in the GRAVITY RESEARCH GROUP of the Freie Universität Berlin. The basic elements are two public domain libraries: VTK for the 3D visualization and XFORMS as GUI-builder. Both parts are X-window based, independent of the graphical kernel and running on all UNIX and LINUX workstations. The easy to use graphical user interface of IVIS-3D allows to control various parameters of the displayed geometries. Some of the main features of IVIS-3D are:

- likewise online (interactive) and offline (batch) rendering
- VRML output format of actual scenes
- automatic screen shots in PPM format
- interactive object identification (picking)
- several predefined 3D-views
- extraction of isoline and different edge types
- model generalization during movement

MULTI-CHANNEL DECONVOLUTION IN GEOPHYSICS AND HELIOSEISMOLOGY

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Whenever data sampling is regular along a coordinate in space and/or time it is relevant to look for approximate shift invariance which casts the forward problem into a convolution formulation. The resulting computations may be speeded up significantly through the Fourier transform. For nonlinear problems the Born approximation in horizontally stratified media leads to just such a result.
In many cases the noise is well approximated by a stationary process, and it turns out that the resulting stochastic inverse solution is then a multi-channel deconvolution. This formulation allows very fast inversion in the periodic approximation of densely sampled high volume data sets.
We present examples of new applications within geophysical well logging, continuous geoelectrical sounding/profiling, and 3D helioseismic tomography.

CONSTRUCTION OF A DETAILED MODEL OF GEOLOGICAL MEDIA BASED ON SOLVING A MULTIPARAMETRICAL INVERSE PROBLEM

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The technological increase in the level of complexity for interpretation of geophysical data becomes necessary for decisions involving difficult geological problems under real conditions (studying tectonics of fault zones, salt domes, areas of reefs, etc.). Recently, in connection with rough development of geophysical information technologies in the practice of interpretation of geophysical data (first of all gravimetry), the series of new methods of complex interpretation with the purpose of construction of detailed models of geological media has come. The rather widely developed theoretical apparatus of these methods (V.N.Strakhov, V.I.Starostenko, A.I.Kobrunov and others) are based on the decision of an inverse problem for multiparametrical models of mediums with obligatory preliminary a-priory definitions by means of specially designed criterion.

The proposed method allows the construction and study of the detailed images of the internal structure of geological objects represented by geophysical data from a variety of methods. Some methodical elaborations and results of automated complex interpretations of geophysical data for the most typical geological models are submitted. Forecasting of oil and gas accumulation zones may also be derived from the automated interpretation.

IVIS-3D goes WWW: how to use offline rendering capabilities for the 3D visualization in the WorldWideWeb

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The overall acceptance and easy access of the WorldWideWeb makes it to an interesting media for fast exchange of a wide range of research information. But unfortunately there is no satisfying Internet technique available for real interactive 3D visualization up to now. High net traffic as well as slow internet servers prevent fast exchange of data, and therefore slows down interaction with remote running programs.
Besides the exchange of VRML files, offline rendering of complex 3D geometries may become a solution to elude these problems. With this technique snapshots of a 3D geometries are computed offline on remote „visualization servers"; the resulting image-files will be send via Internet to the local user afterwards. For instance, offline rendering can be used to combine high end visualization and database queries, even if the related databases and visualization tools are running on remote computers.
With the use of MESA, IVIS-3D (IGMAS **Visualization** in **3D**) now provides this technique in a test case for the GRAVIY RESEARCH GROUP of the Freie Universität Berlin.

To a TECHNIQUE of AUTOMATED COMPLEX INTERPRETATION of GEOPHYSICAL DATA

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The increase of a technological level of complex interpretation of geophysical data becomes necessary at the decision of difficult geological problems in real conditions (studying tectonics of fault zones, salt domes, areas of reefes, and etc.).
Some methodical receptions of automated complex interpretation of geophysical data for the most typical geological models, allowing to carry out construction and study of the detailed images of internal structure of geological objects on a complex of geophysical data, and also forecasting of oil and gas accumulation zones, are submitted.

COORDINATING OF SIMULATED ANNEALING ALGORITHM TO THE TELELESEISMIC DATA INVERSION SEISMIC SOURCE STUDY

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We performed inversion of teleseismic data by Simulated Annealing method looking for the source mechanism, i.e. strike, dip, rake (point source is considered), the depth of the source, the seismic moment and for the STF (representing by 11 equidistant points). For the inversion we used Very Fast Simulated Annealing algorithm. By numerical experiments performed for synthetic seismograms as well as for the real data we discovered that convergence and stability of the inversion is improved by following steps: 1) we changed cooling scheduler and instead of formula $T_n = T_0$ *exp(K) we used $T_n = T_{(n-1)}$*exp(K); the values of the control parameters are set up also. 2) we restricted intervals of possible values of searching parameters: strike, dip and rake +/- 12°, the depth +/-5 km, the moment +/-80% and the values of the STF 0-200% of an unit. 3) we did the normalisations: we normalised all intervals of the parameters to be 0-1; as the azimuthal distribution of the stations for real data is irregular, we added weights to the seismograms - the weights are proportional to the density of azimuthal distribution, we normalised max. amplitude of seismograms; we normalised value of the cost function to be about the order of an unit. Under all theses tunings and changing we were able to have the best convergence of the inversion performed for two real earthquakes: (18 Nov. 1992 in Greece, M5.9 and 14 Sep. 1995 in Mexico, M7.3)

MATHEMATICAL PHYSICS ENGIMA: BENDING SNELL'S RAYS OR STRAIGHT TRAJECTORIES

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While working on a simple procedure for solving the wave equation in a stratified seismo-acoustic medium in the time-space domain, the following new observation was gained in the following manner: It is well known that for solving the strictly 1D wave equation it is advantageous to quantisize the depth into equal travel time sublayers. This allows a rational polynomial, impedance type closed form solution. This solution includes all multiples due to the feedback structure of this procedure.
Extension of this idea to the 1.5D and 2.5D problems (i.e. the model is still horizontally stratified but the source is not a normal plano wave, but a line source or a point source, respectively) has been performed. In order to adhere to the equal travel time sublayers, we may adjust the thickness or the propagation velocities so as to stretch Snell's bended ray into a straight trajectory, without affecting at all the resulting pressure and particle velocities seismograms. Unlike asymptotic ray theory which is a high frequency approximation, the straight trajectories algorithm yields the full correct amplitude seismograms. This poses the question if one could accept the more appealing straight trajectories concept in favour of bending rays?
The straight trajectory idea is more appealing than rays also due to the fact that it does not necessarily need involvement of wave fronts, while rays are defined as normal to them. Further the source(s) may be looked at as emitting particles which naturally move along straight trajectories. Thus the dichotomy between waves and particles may be explained by this novel straight trajectories theory. This may lead to a new foundation of quantum mechanics

LOCAL ERROR CORRECTION TECHNIQUE FOR MAGNETIC ANOMALIES INTERPRETATION IN UNIX-BASED OPEN PROGRAMMING ENVIRONMENT

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We perform 3-D anomalous magnetic total force interpretation by means of local error correction technique. 3-D direct problem are solved for this. Then magnetic properties of model are adjusted on the base of total force residual field destroying and applying of rules constrained solutions. We use a priori information about
- possible physical processes of acquisition by rocks magnetism;
- geological formation of region where magnetic anomalies are located;
- seismological data on the structure of region under investigation.

We actualized this technique in our Unix-based complex Maglab. Maglab use X-windows Scilab tools as a basis for visualization, input, output, transformation and interpretation. Scilab tools were developed by Scilab Group, INRIA, France (http://www-rocq.inria.fr/scilab).
Our technique is suitable for various potential field. Maglab allows us to change type of potential field by means of replacement of modules specific for geomagnetic field.

CALCULATING THE RESOLUTION AND THE COVARIANCE MATRIX WITHOUT USING SINGULAR VALUE DECOMPOSITION

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For large tomographic inversion Ax=b it is still problematic to compute the resolution or a posteriori covariance, which, for a generalized inverse A^- are given by $R=A^-A$ and $C_x=A^-C_b(A^-)^T$, respectively. We have developed a simple backprojection approach to calculate an approximate A^- for large tomographic problems. We have verified that our solution is a good inverse as it satisfies the two Penrose's conditions. We use this approximate inverse to compute the resolution and covariance matrix. We compare the approximate R and C with the exact ones obtained using singular value decomposition for a medium-size problem. We show the results of this comparison and the results of a statistical analysis of the errors in our approximation for two realistic tomographic inversion in the western and eastern United States.

AUTOMATIZED SYSTEM OF 3-D GRAVITY MODELLING: THE MAIN PRINCIPLES AND SOFTWARE

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1. The automatized system of solution 3-D direct gravity problems consists from two main blocks: 1) automatic inputting in computer geophysical maps' image with help of scanner and construct of their digital models and 2) solution of direct gravity problems for 3-D heterogeneous bodies.
2. The procedure, algorithms and software of automatic inputting of data in computer are presented. Algorithm for constructing the digital model of map on its image is offered. The efficiency of elaborated algorithms (set of programs) is demonstrated on model and practical tests.
3. The solution of direct gravity problems for rectangular vertical prism with arbitrary arranger upper and lower bases is given. The prism's density: 1) is changed according to the linear law along the horizontal co-ordinates on the bases and to the exponential law along the any vertical line; 2) is assumed given values at the apexes of the prism.
4. The results of successful practical application of system are given. The examples include materials for different geological and geophysical situations. First of all system is very convenient for sedimentary basin modelling and for carrying out marine geophysical investigations.

VELOCITY STRUCTURE OF CRUST AND UPPER MANTLE BENEATH THE BAIKAL RIFT AND ITS SURROUNDINGS

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Velocity structure of the crust and uppermost mantle beneath the Baikal rift and its surroundings has been imaged due to inversion of teleseismic data from 30 digital seismographs deployed along a 1000 km profile traversing the rift in the SE direction. The inversion algorithm was based on the matrix method for theoretical seismograms and the Tikhonov's regularization method for ill-posed problems. Seismic records were processed by the converted wave receiver function method of L.Vinnik and G.Kosarev. In the P-wave secondary field, Ps- waves, generated at seismic interfaces within 10 to 30 km far from the seismographs, were best informative. They were selected due to projection of three-component seismograms onto the SV axis. To eliminate source effects, each SV component was deconvolved with the P one, and their subsequent summation helped to suppress incoherent noise. P- and S-wave velocity profiles were obtained through inversion of the SV traces separately for each seismograph. The resulting model showed the presence of a low-velocity layer beneath nearly all the stations at depths ranging from 5 to 20 km and abrupt crustal thickening south-east of Lake Baikal (43-49 against 33 km), associated with markedly lower S-wave velocities in the uppermost mantle (4.2 against 4.6 km/s). This setting is, in general, similar to that observed in other continental rifts.
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SEISMIC EVENTS DISCRIMINATION BY A NEURO-FUZZY MERGING OF INCOMPLETE DATA

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We present an original method for the classification of regional seismic events recorded in France by an array of 42 seismometers. Three types of events are discriminated: earthquakes, explosions and rock bursts. The approach is based on a merging of low-level data extracted from the seismic signals provided by the three nearest stations and high-level data deduced by an inversion program developed by the CEA seismologists. The data merging is performed by means of an artificial neural network. A fuzzy coding taking incomplete data into account is applied to the 23 inputs of the neural network. Each event is represented by a possible incomplete vector of five high-level characteristics (the date and the hour of the event, the latitude and the longitude of its epicenter, and its magnitude) and low-level characteristics (cepstrum, power spectral density and propagation time measurements). The results obtained on a database composed of all the 505 seismic events recorded between August 23^{rd} and September 12^{th}, 1993 show that the fuzzy coding coupled with the data merging increases the performance of correct classification up to more than 90% even when the database includes missing values.

JOINT GRAVIMETRIC AND WIDE-ANGLE SEISMIC INVERSION FOR CRUSTAL MODELLING WITH APPLICATION TO THE CENTRAL GRABEN, NORTH SEA.

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A least squares scheme for estimating 2-D integrated crustal velocity-density models by joint inversion of wide-angle seismic travel time data and gravity data is presented. During inversion we assume some relationship between seismic P-wave velocity and density, and we use this relationship to produce a priori data which constrain how velocities and densities should be linked. Simultaneously, the inversion optimizes the solution with respect to these a priori data as well as to the observed gravimetric anomalies and seismic travel times. Working with integrated wide-angle seismic and gravimetric modelling one will note that considerable scatters exist on commonly used relations which link P-wave velocity and density. We take the amplitude of such scatters into account by specifying large or small uncertainties on the a priori data expressing the link between densities and velocities.
The behavior and performance of the inverse scheme is tested in some simple synthetic test examples. We illustrate how the estimated integrated velocity-density models depend on seismic ray coverage, the presence of gravity data and the uncertainties in the velocity-density relationship. Finally, we present an integrated velocity-density model along a profile across the Central Graben, North Sea.

THE REGIONAL COMPONENT OF THE GRAVITATIONAL FIELD INVESTIGATION FOR THE URALS AND ADJACENT PLATFORMS.

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The new technique for the distinquishing of gravimetrical fields' regional component has been considered while the deep density Earth crust models constructing using the profile data for the super long geotraverses. The suggested technique is based on the principal results of the theory of equivalent solutions for the inverse potential fields' problem. The regional component for the gravimetrical field has been obtained for a number of lattidudional geotraverses crossing the Southern Urals and adjacent platforms. The length of these geotraverses 1200-1500 km. The gravitational data for geotraverse "Granit" with the length 3700 km were also under investigation. The main feature of the obtained regional fields is the noteable decreasing (minimum) of these fields above the main Urals structures in comparison with the neighbouring platforms. The length of this negative anomaly is about 350 km and it can be traced for all geotraverses on the Southern Urals and for the geotraverse "Granit" as well. This fact seams to be interesting because the absolute maximum of the field for all the investigated geotraverses is situated above the Urals structures. The obtained long-wave negative component of the gravitational fields for the Urals should be taken into account while deep density models' constructing.

THE INVERSE PROBLEM FOR MANTLE VISCOSITY: NEW RESULTS BASED UPON JOINT INVERSION OF GLACIAL ISOSTATIC ADJUSTMENT DATA

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The depth variation of viscosity in Earth's mantle is critical to understanding the efficiency of mixing and radial heat transport. Although viscosity may be inferred on the basis of data related to the convection process itself, such as non-hydrostatic geoid anomalies, inferences based upon the internal loading formalism that employs results of global seismic tomography to make theoretical predictions of these observations delivers results for the viscosity structure that are highly non-robust. The addition of seismically undetectable additional heterogeneity to the model may lead to radical differences in the inferred viscosity structure. Although inferences based upon glacial isostatic adjustment (GIA) observations are certainly not unique, they appear not to be nearly so sensitive to minor variations of the surface ice-sheet load whose removal forces adjustment to occur. I will describe a new series of Bayesian inversions of a wide range of GIA data that include the relaxation spectrum for the postglacial rebound of Fennoscandia, a very large number of site specific relaxation times from both Fennoscandia and Canada and two anomalies in Earth's current rotational state. The models delivered by this formal procedure differ radically from those recently advocated on the basis of non-hydrostatic geoid anomalies. I will discuss these differences in detail.

NUMERICAL MODELLING OF T-WAVE PROPAGATION

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Strong T-waves, referred to a third arrival on seismic waves, are commonly recorded on coastal stations, at distance greater than 1000 *km*, after an oceanic earthquake or an underwater explosion occurs. Many insights could be provided by these records, once they could be interpreted. We propose a new hybrid numerical scheme, combining in a single approach two powerful techniques, a ray tracing method completed by the Maslov summation and a finite difference scheme, which allows us to model T-wave underwater propagation and on-land conversion, including complex interactions with obstacles. In our modelling, before the T-waves arrive in front of an obstacle such as a continental shelf, an island shore or a sea-mount, the propagation is resumed on a vertical artificial boundary and the hydroacoustic wave field is considered as the input for a finite difference method. Records of the (1989) Midplate experiment released in the South Pacific have been used to demonstrate that our hybrid method is particularly relevant for studying T-wave underwater and on-land propagation. Synthetic seismograms computed by this method are close enough to the real data for quantitative interpretation. The simulation shows that the seismic T-wave duration is often linked to the source depth, although other factors (*e.g.* the geological structure) may also affect the signal duration.

NEW TWO STAGE APPROACH FOR 3D POTENTIAL FIELD DATA INVERSION

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The preliminary condition for joint inversion is,from the author viewpoint, to solve every inverse problem in the best way, that is with taking into account the non-uniqueness of the solution and for 3D objects of arbitrary shape. For the interpretation of gravity or magnetics data two stage approach has been invented. On the first stage the observed field is approximated by the field of several elementary sources. We use the new source - homogeneously magnetized magnetic rod or gravitational rod. Very few of these sources would be enough to approximate quite complex observed field. On the second stage we construct a restricted body or a contact surface with the same field as the field of a given set of the rods. On this stage we are able to study different variants of geological section to take into account the non-uniqueness of the inverse problem. Two case histories demonstrate the facilities of our approach. 3D relief of the upper boundary of pre-jurassic rocks was found using square gravity data mainly. Subsequent comparison of the relief obtained with the position of the boundary according to the seismic profile, unknown for the author beforehand, has revealed their quite satisfactory coincidence.The volume model of Kendykty granitoid massif has been constructed. 3D geometry of the diorite core in the granite block has been recovered, which lower boundary was expected to be a metallotect.

METHODICAL PROBLEMS AND TECHNIQUES OF RECONSTRUCTION OF TECTONIC STRESSES AND SEISMOTECTONIC DEFORMATIONS USING THE SLIP FAULT ANALYSIS

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The new method of deformation process parameter reconstruction by analysis of structure-kinematics data about faults (SKDF) is offered. The method of 'cataclastic analysis' permits to reconstruct the tensor parameters not only of tectonic stresses but seismotectonic deformations also. The method is based on the principles of modern theory of work-hardening plastic solid that was expended for the deformation process into a faulted medium. The main procedure of the method is the creation of a homogeneous sample of faults. To execute this procedure, the compatibility of SKDF is checked by nonequality system that demands positive dissipation of mechanic energy for true stress tensor. In the framework of the computer program of stress-monitoring, the technique of 2D graphical analysis of nonequality system on the sphere surface was used to check the SKDF homogeneous. The computer program shows the process of graphical data calculation during creation of the SKDF homogeneous sample and the maps of the principal stress axes on the computer monitor. The results of this method implication and the reconstruction technique of the recent stress state of South East Asia and Oceanian is illustrated.

IRREGULAR CELL PARAMETERIZATION OF TOMOGRAPHIC PROBLEMS

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We have developed theory and algorithms for the construction of highly irregular cell parameterizations of tomographic problems. The forward problem is defined on a regular basic grid of small non-overlapping cells. We construct an irregular grid of non-overlapping cells using basic cells as building blocks. The algorithms developed for the construction are not computationally intensive and not particularly complex, and, in general, allow for the construction of cell models in which cell size is constrained by scalar functions, such as cell hit count. The link between a particular cell j in the regular basic grid and its host cell k in the irregular grid can be stored in a simple pointer array. The pointer array is the pivot of our implementation of irregular cell models. The matrix system of tomographic equations is first computed efficiently on the regular basic cell model. This computation is performed only once. Next, this basic matrix equation is mapped, using the pointer array, onto a new matrix equation in which the model vector relates directly to cells in the irregular model, after which the latter can be solved on the irregular grid. A great reduction of model parameters is obtained in volumes poorly sampled by the data while retaining the power for resolving the smallest scales warranted by the data. Overparameterization of the model space is avoided, and the reduction in model parameters potentially leads to a better conditioned inverse problem.

A DENSITY MODEL OF ANDEAN SUBDUCTION ZONE

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Several different geodynamic models have been proposed to outline the evolution of Andean lithosphere and to explain the nature of the thickened continental crust. We tested by density modeling (2D profile along 21° s) the following version:
1. The upper crust of the Ands is a long-range mostly Ordovician and Devonian back-arc sedimentary marine basin, which was affected by episodic orogenesis and riftings between Miocene and Ordovician, and also by magmas of the volcanic arc. Now the upper crust layer has shape of a lens, thickening up to (20-25) km beneath the Cordillera mountain belt and edging near the coast and Subandean thrust.
2. A part of this basin between the coast and Western Cordillera was underthrusted by a complex of island volcanic arc, presumably in the Late Jurassic.
3. Beginning from the Miocene, the crust beneath Eastern Cordillera and Subandean ranges has been thickening by underthrusting of the Brazilian craton crust. A whole length of crustal doublication by this manner is estimated not less ~300 km.
4. A seismic Moho has not observed beneath the Plateu Altiplano and present-day volcanic arc Western Cordillera. The lower crust and uppermost mantle here are unknown nature, but the material must have been strongly affected by magmas and reworked by metamorphism and tectonics. The approximative depth (~70 km) of quartz-coesite transformation is addopted as a conventional crust/mantle boundary.

Model of crustal and mantle density down to 670 km depth was produced with linear gravity inversion tecnique. Densities were constrained where possible by borehole and seismic velocities data, and petrological arguments. We assumed also that the lithosphere is close to isostatic equilibrium in the deep ocean and east of the volcanic arc. Density modeling showed that the geodynamic model agrees to the observed gravity field. No marked horisontal density homogeneities were obtained in the lower crust beneath Western Cordillera and Altiplano; the average density here was determined higher of ~0.1 g/ccm, than the lower crustal density of the Brazilian craton. A intermediate crust/mantle density (~3.2 g/ccm) was obtained in the mantle edge.

A NOVEL METHOD FOR THE INVERSION OF RELATIVE DISPLACEMENT DATA: JOINT ESTIMATION OF CONTINUOUS CRUSTAL DEFORMATION AND FAULT SLIP

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We present a new inversion method for the estimation of 2-D or 3-D crustal deformation from relative displacement data (obtained e.g. from GPS or SAR interferometry). The inversion solves simultaneously for the deformation gradient field (DGF) and for slip vectors on active faults. The DGF is parameterized by triangulation of the study region with the constraint that triangles do not cross faults. In each triangle, linear behaviour of the DGF (quadratic displacement) is assumed. Fault geometry is parameterized as sequences of line segments on which fault slip functions (e.g. step, linear, or spline) are defined. The forward equations are based on a line integration approach in which the relative displacement between any two observation points results from (1) the integration, along some connecting path, of the piecewise continuous DGF, and (2) the sum of all discrete fault slips acquired along the integration path. By connecting all observation points by one or more integration paths a system of linear equations is set up for inversion. As extra constraint is used that the curl of DGF is zero. The method is purely kinematic and is kept independent of any a priori dynamic model of continuous deformation or fault behaviour.

INTEGRATION OF DATA CONSTRAINTS AND POTENTIAL FIELD MODELLING - AN EXAMPLE FROM SOUTHERN LOWER SAXONY

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Three-dimensional (3-D) interactive geophysical modelling permits integrated processing and interpretation of potential field data, yielding an improved geologic interpretation. Generally 3-D models are constructed by triangulated polyhedra and constant density and/or induced and remanent susceptibility. Interactive modification of model parameters (geometry, density, susceptibility), access to the numerical modelling process and direct visualization of both, calculated and measured fields of gravity and magnetics, enable the interpreter to design the model as realistic as possible (Trial and error' method).

The data base which is available in a reasonable large area in the southern part of the northwest Germany basin consists of borehole data, vertical seismic cross-sections and depths information from seismic reflection research. The 3D model geometry was compiled on base of these data after proving the structural (geological) consistency. The modelling method is embedded in an interoperable Geoinformation System (IOGIS) which was built on top of an object-oriented database management.

INTEGRAL EQUATION FOR A 3D POTENTIAL INVERSION PROBLEM

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The practical problems of gravity and magnetic prospecting are often solved by the methods of interpretation of gravity and magnetic anomalies (V.N.Strakhov, V.I. Starostenko, D.Zidarov and others). The related potential inversion problems have been studied in many works. More interesting are those that can be solved in a closed form. V.K.Ivanov showed that a 2D problem of determination of mass carriers can be solved in a finite form if a given external potential satisfies certain conditions. According to Ivanov, a problem is considered to be solvable in finite form if a boundary of a sought-for domain D is specified with a finite number of parameters, which can be found from a finite system of equations constructed from a known potential or other field element.

Many authors (e.,g., M.S.Zhdanov, A.T.Tsirul'skii, G.A.Troshkov) tried to apply the methods developed for solving 2D inverse problems to the case of 3D problems. The method presented in this topic for the solution of 3D nonlinear inverse problems is a generalization of Ivanov's approach. Domains of certain class (so called "basis cylinders" and their set) make it possible to derive 3D integral potential equation that is applicable to solving inverse problems.

The introduction of new independent variables $\sigma = x+iy$, $\overline{\sigma} = x-iy$ allows us to apply the complex variable theory methods to the solution of 3D inverse problems. In this work, the inverse problem is formulated both for a 3D "basis" cylinder and for domains that can be represented by a finite union of basis cylinders.

THE INTEGRAL REPRESENTATION METHOD AT THE SOLUTION OF 3D INVERSE PROBLEMS IN GRAVIMETRY AND MAGNETOMETRY

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1. The integral representation method was designed by Beikus and Gilbert. This method has to substutude, in the opinion of the authors of this report, the integral equation method, because only the first one is adequate to the real geophysical practice, when only a finite set of experimental data is given,which contains the information about anomalous field elements.
2. We represent the experimental data in the following form:
   $f_{i,\delta} = f_i + \delta f_i$, where f_i is the value of the useful signal and δf_i is the value of the noise. We suppose,that the useful signal can be expressed by the formula:
   $$f_i = \sum_{r=1}^{R} \int_{M_r} K_r(x, \rho_r(x)) d\mu_r(x),$$
   where $K_r(x, y)$ is the given function, M_r is the given manifold in R^3, $\mu_r(x)$ is the given measure. The functions $\rho_r(x), r = 1, \ldots, R$ are to be found.
3. The simplest case takes place, when we solve the linear inverse problems, especially when the spatial distributions of the anomalous fields are to be determined. The sought-for functions are the solutions of the related variational problem. Some modifications of the method described above have been realized in computer programms. Some results of the mathematical experiment are reported.

SOME TECHNICAL DETAILS CONCERNING A NEW METHOD OF JOINT GRAVIMETRIC-SEIMIC INVERSION

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Abstract: The fundamental problem of joint gravimetric-seismic modelling is, that the information about the object(s) of inversion, which is contained in surface data (gravity, seismics), is insufficient to unambiguously determine the geometrical shape of these object(s). One factor causing this "insufficiency of information" is the imperfection of the available data (both the spatial distribution and the measurement errors). Another factor is the uncertainty in how to couple the two types of data. (Are the seismic reflectors always associated with the mass density contrasts? What are these contrasts? Surface gravity data may contain contributions generated in depths below the penetration depth of seismograms. How to describe this inconsistency mathematically? The seismograms are measured in profiles, while gravity data have aerial coverage.) Finally, it can be shown that the mapping from the source to the surface signal (e.g. Newton's law) is associated with the "loss of information". (This is the reason why the inverse geophysical problems are often mathematically ill-posed.)

Consequently, the usual mathematical assumptions ensuring the uniqueness of the solution (the choice of a solution space, the choice of error statistics, the choice of minimization principle) will not automatically ensure that the solution is a good approximation to the (existing) true physical conditions in the subsurface. This requires inclusion of (independent) additional information, e.g. obtained by other geophysical methods. However, the remaining pitfalls are the first two factors mentioned above.

In this contribution it is discussed how the above general considerations can be implemented in practical modelling. This is illustrated by discussing some technical details implemented in a newly developed joint gravimetric-seismic inversion method which was used in modelling of Silkeborg intrusion in Jutland (Denmark).

EGS4 Space techniques for acquisition of aeronomic-ionospheric data in the lower thermosphere

Convener: Laneve, G.
Co-Convener: Herrero, F.A.

Sponsorship: CRPSM (Centro di Ricerca Progetto San Marco)

GROUND-BASED HF LONG-DISTANCE MEASUREMENTS TO STUDY THE IONOSPHERIC MODIFICATION PRODUCED BY SATELLITE AND TETHER ACTIVE EXPERIMENTS

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High-resolution multichannel measurements of HF signals by Doppler method are proposed as a research tool in studying of ionospheric disturbances initiated by satellite and tether active experiments. Doppler measurements are carried out at the net of long-distance HF radio paths intersecting the disturbed region of the ionosphere and having the common reception point in St.Petersburg. For measurements any HF broadcasting transmitters including world band radio can be used. By way of illustration the results of experimental studies during the CRRES Barium release on 13 July 1991 are considered. The length of research radio paths was from 5900 to 11000 km. The analysis of Doppler measurement data showed the presence of medium-scale ionospheric wave disturbances with main periods in the range of 47-58, 19-24 and 10-13 min during CRRES Barium release. It is evident that wave processes of periods about 10-13 min are caused by Barium release and wave processes of periods 47-58 and 19-24 min have a natural origin. Some peculiarities of dynamic Doppler spectra on different radio path can be explained on the assumption that the release is the source of ionospheric disturbances propagated for long distances (550-2200 km) with supersonic velocities in the range of 1000-2700 m/s.

SOME PURPOSES AND METHODS OF THE SATELLITE MEASUREMENTS OF THE IGNOROSPHERIC RESPONSE ON THE SOLAR FLARES

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The most intensive response on the solar flares takes place at the altitudes near 100 km. The response consists in the increase of the degree of the ionization and in the intensification of the photoelectron spectrum and of the optical emission of the upper atmosphere. However the complex measurements of the response on the solar flare still have not been carried out because *in situ* measurements at given altitudes are very difficult. The paper describes methods of these measurements including small tethered systems. The small tether satellites are very suitable for the following experiments: 1. Measurements of the ionospheric photoelectron and Auger electron spectra because there is no large shadow effect from the satellite body at large pitch-angles and also parasitic photoelectron fluxes from the satellite body are small. 2. Measurements of the increase emissions of the upper atmosphere and for the investigation of the altitude and size dependence's of the satellite glow. 3. Measurements of the increase in the electron and ion densities including mass-spectrometric registration of the double charged ions which formed due to Auger effect at the altitudes of ignorosphere.

OPTIONS FOR COORDINATED MULTI-POINT SENSING IN THE LOWER THERMOSPHERE

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This paper discusses and critically compares various options for co-ordinated multi-point sensing in the lower thermosphere. The focus is on low-cost near-term options, including Ariane secondary payloads. The paper includes a matrix showing the feasible mission goals, constraints, and relative complexity of each option. For example, two concepts using tethers are discussed. Both can use existing flight-proven tether deployers. One is a vertical string of small satellites deployed "daisy-chain" fashion. The tether provides passive station-keeping and 2-axis attitude control, allowing use of fairly simple satellites. High tether drag may limit mission durations to a few days. The second option uses a librating tether to drop many subsatellites into eccentric co-planar orbits with complementary perigee altitudes and phases. This concept keeps tether drag and cut risks from limiting mission duration, but requires somewhat more capable subsatellites. For a more challenging mission involving multiple passes at perigee altitudes below 100 km, Ariane secondary payloads released in GTO seem very attractive. The excess orbit energy in GTO allows many low-perigee passes before reentry, and each perigee pass is brief enough to limit aeroheating problems. In addition, slight differences in perigee altitude between satellites can quickly spread an array out. This allows good separation of temporal and spatial phenomena in the lower thermosphere.

NEW INSTRUMENTAL TECHNIQUES FOR IN-SITU MEASUREMENTS IN THE LOWER THERMOSPHERE/IONOSPHERE

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Two instrumental techniques are discussed in terms of their applicability for *in-situ* measurements in the lower thermosphere and ionosphere. The first provides composition information using a recently-developed mass spectrograph that incorporates a time-dependent electric field. The instrument has advantages over previous measurement techniques because it simultaneously registers particles across a broad range in mass, and is therefore intrinsically fast. Other performance advantages include its compact, lightweight package and simple construction. The principles of operation are described and test results from a prototype instrument shown.
The second technique explores the medium surrounding a spacecraft through the use of a charged particle beam. A low-current beam is emitted perpendicular to the ambient magnetic field, returning to the spacecraft through gyromotion where it is detected by the instrument. Measurement of the return current provides information on the ambient medium and allows study of the collision processes occurring there. Many beam energies are utilized to include a variety of mean free paths and to examine the energy dependence of these processes. The results of model calculations utilizing this technique are shown, and the potential of the methodology for scientific return is discussed.

GEOSPACE ELECTRODYNAMICS MISSION

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A line of Solar Terrestrial Probe satellites have been designated as part of the actualization of the strategic plans laid out in NASA's Sun-Earth Connection Roadmap. The Solar Terrestrial Probe missions currently under definition include a series of geospace multiprobe missions: Magnetospheric Multiscale, Geospace Electrodynamics, and Magnetosphere Constellation. The Geospace Electrodynaics (GED) Mission goal is to explore the electromagnetic coupling between the sun, magnetosphere, and upper atmosphere. As currently envisioned, it will consist of multiple satellites in similar orbits which dip to altitudes below 150 km to explore in better spatial and temporal detail than before the coupling regime between the atmosphere and magnetiosphere. An overview will be given of the current status of the GED mission.

MEASUREMENTS OF THE ALTITUDE DISTRIBUTION OF THE HORIZONTAL WIND WITH "WEATHER-VANES" ON A TETHER SATELLITE

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A vane attached to the tether on the Tether Satellite system is expected to align along the velocity vector of the air flowing around it. An array of vanes on the tether, separated from each other by known distances, may yield the vertical variation of the horizontal wind. Analysis of the problem shows that the motion of the vane is very sensitive to initial conditions and thereby to small changes in the wind and density of the air; the period of oscillation changing chaotically as the tether moves through the air. Tight coupling to the tether may damp the oscillations induced by air perturbations and may make it possible for the vane to line up with the wind. This study naturally leads to the proposal for wind measurement with an array of vanes on the tether. Implementation with an optical system to track and record the angular displacements of all the vanes is discussed. Tether aerodynamics play an important role in the implementation of this idea, as well as the problems associated with deployment the vane array along the tether.

WAVE-LIKE VARIATIONS AND SUDDEN DENSITY DECREASES IN THE LOWER THERMOSPHERE AS MEASURED BY THE SAN MARCO V SATELLITE

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Neutral density measurements were carried out by the micro-accelerometer on board the Italian San Marco V satellite in 1988. During the final week of its existence the satellite's perigee decreased to as low as 130 km. Measured density values were compared to the corresponding CIRA'86 (MSIS'86) model values. The residuals reveal a wavy structure of different time scales. Characterising the wave amplitude by the average deviation of the residuals, its dependence on different parameters was studied. These investigations demonstrated that the wave-amplitude varies with height, local solar time and geomagnetic disturbance level. There is a particularly developed wave pattern in the average deviations below 200 km. Case studies indicated also that there are sudden density decreases of 10 - 20 s duration that might be in connection with plasma bubble crossings by the satellite, as the occurrence of such events maximises in late evening hours, similarly to plasma bubbles.

ELECTRODYNAMIC TETHER SYSTEM

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The tether systems are a new challenge in space activity. They have two major aspects of application. First one is to go as far as possible with very sensitive instrument away from noisy satellite, using nevertheless its telemetry, data processing and power supply facilities. One of the first good examples of such solution is the combination of flux-gate magnetometer sensor and star imager sensor mounted on one optical bench tethered by flexible cable to the satellite. The parameters of star imager allow to realize «lost-in-the-space» conception at practically any distance from mother satellite. Second is to study the lower ionospheric layers not accessible neither for satellites nor for balloons or aircrafts. Many interesting phenomena for example Es layers formation, electrostatic jumps of high amplitude etc., still are waiting for in-situ investigation. Both these aspects are discussed and the last is especially emphasized. Besides the scientific investigations long tethered ropes moving in Earth's magnetic field can be used both as new source of power supply or electrodynamics braking/acceleration system. Such possibility is of special interest now because of the development of International Scientific Station ALPHA. The preliminary experiment onboard of MIR station is proposed in order to study the dynamics of the tethered conductive rope. The efficiency of this applications is discussed and calculation showing possibilities of practical implementation are presented.

SMALL SATELLITES FOR STUDIES IN THE LOWER THERMOSPHERE

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A solution of the problem of filling the gap in aeronomic data at altitudes ranging from 130 to 200 km was proposed based on the exploitation of a tethered satellite deployed for 100 km or more from the Shuttle. But this solution seems to be still far away from implementation. So, this paper is devoted to study the possibility of using a satellite on a very eccentric orbit (around 0.5) as a possible alternative, more rewarding in terms of cost and reliability. The characteristics of the orbit, inclination, semi-major axis, etc. can vary according to the type of study to be performed. In particular this paper is devoted to study the possibility of making the satellite an integral part of the scientific measurements determining analytically his orbital characteristics in order to emphasize the study of particular phenomena. In fact, particular phenomena and corresponding particular orbital characteristics will be discussed. In addition to the altitude, the Earth's Thermosphere characteristics depend mainly on the latitude and solar local time. Thus we intend to explore the possibility of starting from thisstatement, for determining the necessary rate of variations of right ascension of the ascending node and perigee argument, to meet our necessity in terms of latitudinal and solar local time coverage and then determine the characteristics of a suitable orbit in terms of semi-major-axis and inclination. We intend to go one up on the Explorer satellite experience by using satellites, on very eccentric orbits, to sample the lower thermosphere region: selecting the orbit and studying a constellation of small satellites oriented to aeronomic studies.

ELECTRIC FIELD MEASUREMENTS IN THE LOWER IONOSPHERE (80-150 KM) USING SOUNDING ROCKET PROBES

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DC and wave electric fields are important parameters that characterize the Earth's lower ionosphere. At the magnetic dip equator, for example, polarization electric fields are set up within a narrow altitude layer (100-110 km) which subsequently drive the equatorial electrojet Hall current. At mid latitudes, such fields may also be sustained within sporadic-E layers, as well as within gravity wave crests. At high latitudes, electric fields map down from the magnetosphere where they may drive strong auroral electrojets between 90-135 km. In conjunction with gradients in the plasma number density, the DC electric fields also drive a variety of plasma instabilities (e.g., two-stream, gradient drift) which may include surprisingly large wave electric fields (e.g., $\delta E/E \sim 1$). *In-situ* investigations that measure both DC and wave electric fields are commonly carried out using double probe detectors on sounding rockets, often in conjunction with other *in-situ* measurements as well as ground based (e.g., radar) observations. Although ion drifts in these regions are slowed by ion-neutral collisions, the combination of the electric field and ion drift measurements on sounding rockets provide a measure of collision frequencies as a function of altitude. Electric field measurements on sounding rockets in the lower ionosphere are reviewed in this talk, with an emphasis on which platforms create the highest quality data. Magnetically-aligned payloads with long electric field booms in the spin plane (i.e., perpendicular to the magnetic field), as well as payloads with a very small central body, appear to give the most reliable measurements.

EXPLORATION OF THE LOWER IONOSPHERE AND THERMOSPHERE USING IN-SITU MEASUREMENTS ON LOW PERIGEE SATELLITES

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The lower ionosphere and thermosphere (80 - 200 km) constitutes one of the most complex and important regions in the Earth's space environment. *In-situ* measurements within this region are difficult for satellites since the large neutral number densities create a high drag environment. The drag not only may significantly alter the satellite orbit, but the interactions of the satellite with the high density neutral gases may adversely affect the operation of several *in -situ* instruments, as well as create thermal problems. Although such problems become quite severe below ~115 km and prohibitive below ~100 km, successful measurements appear to be feasible down to at least 120 km, thus enabling observations of a rich variety of important plasma and neutral gases to be carried out. This talk presents an overview of a mission currently being proposed to NASA to carry out such low perigee measurements of DC electric and magnetic fields and waves, vector neutral winds and ion drifts, plasma and neutral gas number density, composition, and temperature, energetic particles, and lightning flashes. We describe orbit scenarios to achieve coverage at all local times, seasons, and latitudes and discuss other unique features of such low perigee satellites in view of designing a comprehensive, robust mission that contributes important, new knowledge concerning the Earth's low altitude, near-space environment.

SOLID EARTH GEOPHYSICS (SE)

SE1 Open session on tectonophysics

Convener: Sabadini, R.

PRECISE TIME CONSTRAINTS ON THE EVOLUTION OF AN EXTENSIONAL BASIN FROM THE COASTAL RANGE OF CENTRAL CHILE.

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The construction of P-T-t trajectories for very low-grade metamorphic episodes in thick volcanic sequences of extensional basins contributes to the knowledge of the geodynamic evolution of mountain belts. The main difficulty is to obtain precise age constraints on both primary and metamorphic minerals of the same rocks. $^{40}Ar/^{39}Ar$ analyses were performed on basaltic andesites from a 10 km thick sequence of marine and continental volcanic and sedimentary rocks of Early Cretaceous age from the Coastal Range of Central Chile. This sequence was deposited in a back-arc basin during an extensional episode, and then affected by burial, non-deformative, low-grade metamorphism. Mineral assemblages of the zeolite and prehnite-pumpellyite facies are abundantly present most particularly as amygdale fillings with pumpellyite + adularia + chlorite ± quartz ± epidote. Bulk samples of primary, unaltered, plagioclase and single grains of adularia (in amygdales) from the lavas displayed an age of 119.5 ± 1.3 Ma for the lava formation, and ages ranging from 93.5 ± 0.3 to 94.2 ± 0.2 Ma for the metamorphism. Intermediate ages are well correlated with the sericitisation degree on single grains of plagioclase. The period of 25 Ma between volcanism and metamorphism yields insights on the geodynamic evolution of this extensional basin.

STRESS VARIATIONS IN SEISMIC ZONES ARE CLEARLY REFLECTED IN LONG TERM AND DIURNAL GEOMAGNETIC VARIATIONS

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When comparing long term geomagnetic variations in seismically active regions with the changes in seismic activity during the 20th century a remarkable congruence appears. Moreover, such a relation can be observed in the diurnal range of variations, too. Several examples of this phenomenon will be presented first, concerning the earthquake activity in Austria and in main seismic regions of China, Japan and Italy. These observational results have been obtained in a two years research program at the Central Institute in Vienna.
Out of several models which have been considered in order to interprete this obvious relation, the most trustworthy model is that of a changing magnetic susceptibility of crustal rock under varying stress. It can been shown that this model fits the geomagnetic field variations also quantitatively.The results provide a very surprising and new insight in the tectonic processes of several major earthquake regions.

HORIZONTAL COMPRESSION OF A LAYERED SEQUENCE: FOLDING OR THRUSTING?

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Some examples of deep and/or ductile crystalline basement beneath fold zones at the inner part of a mobile belt and, vise versa, shallow and rigid basement beneath thrust belts at the outer part of such a belt led us to the following hypothesis. In case of deep and/or ductile basement, synclines in above layered sequence can deepen, under horizontal compression, as free as adjacent anticlines grow. In case of shallow and rigid basement, however, synclines can't deepen, so thrusting develops instead of folding. This hypothesis was confirmed by small-scale physical modeling as well as by computer simulation. The experimental duplex structure resembles the computer one, the latter being based on smooth (not angular!) ramp-flat geometry that is a characteristic feature of the former as well as back-to-front sequence of active ramps. The concept of two-stage convection within the tectonosphere (asthenosphere + lithosphere) [Goncharov, 1995-1997] have been used to explain the origin of horizontal compression and extension in different parts of a mobile belt.

THE HARZ MOUNTAINS, GERMANY: THE RESULT OF WRENCH-FAULT TECTONICS ?

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Different tectonic models exist for the evolution of the Harz Mountains. One of the models considers the Harz within a wrench-fault-system. Previous results of gravity and seismic studies revealed an uplift of the Harz Mountains by 3–4 km compared to its surroundings. Based on these information and taking into account that the east–west extent of the Harz is 120 km, a shortening of less than 1 km of the Harz along the same direction has been estimated from geometric models. In order to study the plausibility of this tectonic model, computations with the finite–element method have been carried out. The physical properties of the lithosphere are considered, mainly based on the Prelimenary Reference Earth Model. The calculations cover a range from a homogeneous single layered model to a homogeneous multiple layered model. The latter one also takes into account the lateral inhomogenities due to the Palaeozoic sediments of the Harz and the Ramberg Granite. This model, being the most realistic, reveals a maximum vertical displacement of 550 m in the western area due to shortening of 1000 m during a period of 60 million years, whereas the uplift in the eastern part is only about 430 m. In order to explain the observed displacement of 3400 m at the northern fault zone of the Harz Mountains, a vertically acting force of 40 MPa was required.

TRENDS IN DEFORMATION PATTERNS IN THE DANISH AND SURROUNDING AREAS INVESTIGATED BY 3-D FINITE ELEMENT MODELLING.

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The deformation pattern of the lithosphere depends on its thermal and rheological structure and the stress field.
In a geodynamic context the Danish area functions as a transition zone between the relatively stable Baltic Shield with thick (ca. 200 km) lithosphere and Precambrian crust and the thinner lithosphere to the west and south dominated by Phanerozoic crust. The regional stress pattern is believed to be dominated by forces connected to the continent-continent collision of Africa and Europe, and to ridge push forces related to the spreading at the Atlantic Mid-Ocean Ridge.
The occurence of small earthquakes and local differential vertical movements indicate that the region is subject to deformation. To see how this deformation is related to the regional stress field, the area has been studied using 3-D thermal and mechanical finite element modelling. The model includes sediment and crustal structure.
Modelling results show that the strength of the lithosphere varies significantly over the area and that the pattern of vertical surface movements depends critically on the direction of the stress field. This may be used to explain some of the observed neotectonic features in the area.

THREE SIMPLE DERIVATIONS OF GUTENBERG-RICHTER LAW

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Data for about 150 earthquakes, EQ, illustrate well that L, the cubic root of the seismic moment M over the released stress, is a good measure for the fault length, the shift along the fault and its area $S \approx L^2$. The ratio L/h, h the brittle creest thickness, is the similarity parameter for EQ explaining why the frequency-intensity spectra near mid-oceanic ridges are steeper than the rest. The ultimate forcing for all 3 derivations is the global geothermal flux. The similarity arguments lead to M^{-1} dependence for $L/h > 1$ and to $M^{-2/3}$ dependence for $L/h \ll 1$. The energy balance arguments for cases when the whole crust is torn and for pastial tearing produce the two dependencies on M. The third derivation deals with the work spend on the destruction surface formation and produce -2/3 dependence. An outline for possible future studies is presented.

RIDGES AND DEPRESSIONS: TRANSVERSAL ONES IN SPREADING ZONES AND LONGITUDINAL ONES IN COLLISION ZONES, AS A RESULT OF TWO-STAGE CONVECTION

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Systems of transversal ridges and depressions in spreading zones, ridges being cut by rift valleys and depressions coinciding with transform faults, are similar to systems of longitudinal ridges and depressions in collision zones. The similarity consists of thicker crust, with traces of compression and thrusting, beneath ridges, and, vice versa, thinner crust, with traces of extension, beneath depressions. This morphological similarity gives a reason to suspect some general cause of origin of both the systems. An explanation is given by means of two concepts: (1) Formation of elongated transversal convection rolls in spreading zones [Kirdyashkin, 1989]. (2) Two-stage arrangement of convection in collision zones [Goncharov, 1995-1997] as well as in spreading zones, with thickening of the crust within convection rolls and formation of "roots" beneath ridges, and its thinning between these rolls. The bottom of the geosphere under convection coincides with the bottom of the asthenosphere.

TRANSFORM FAULTS AT MID-OCEANIC-RIDGES AS A RESULT OF DIFFUSED HETEROGENEOUS EXTENSION OF MEDIUM WITH TRANSVERSAL CONVECTION STRUCTURE

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An attempt was made to explain: (1) Coincidence of transform faults (TFs) strike and maximum extension axis direction, including mid-oceanic-ridges (MORs) with oblique cutting TFs, in spite of fundamental laws of rock mechanics. (2) Echelon-like disposition of rift valleys witihin MORs. (3) Thinner crust, with traces of extension, within TF zones, and, vice versa, thicker crust, with traces of compression and thrusting, between these zones. An explanation is given by means of three recent concepts: (1) Origin of elongated transversal convection rolls [Kirdyashkin, 1989]. (2) Two-stage arrangement of convection, with thinning of the crust between rolls [Goncharov, 1995-1997]. (3) Diffused heterogeneous extension of the medium [Talitsky, 1990] along transversal rolls, with formation of echelon-like arranged rift valleys, and their junction along bands of thinned crust, by means of formation of TFs, in accordance with canons of plate tectonics.

GEOTHERMAL GRADIENT VARIATIONS IN IRAN AND THEIR GEOTECTONIC IMPLICATIONS

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Geothermal gradients were calculated for various structural zones of Iran using bottom hole temperatures in oil wells. Typical values for tectonic subdivisions of the country reveal significant variations. Highest gradients of 26-34°C/km, are obtained for the Kopeh Dagh zone of NE Iran and the Caspian coastal plain. N central Iran is characterized by rather uniform gradients near 25°C/km, whereas gradients in the simply folded Zagros begin with remarkably lower values of ~ 11°C/km in the inner zone, and generally increase towards the Persian Gulf where values of 28-35°C/km are reported. Regions marked with higher geothermal gradients in the northern parts of the Iranian Plateau are also characterized by high S_n and P_n attenuations. Additionally, the Alborz mountain range that began rapid uplift since the Pliocene to further separate the Caspian coastal plain and central Iran, in contrast to its high elevation, is distinguished with no root based on gravity data. The rapid uplift associated with anomalous heat flow, high seismic attenuation, isostatic overcompensation, and the Late Neogene-Quaternary volcanic activity all indicate that an anomalously hot upper mantle underlies the northern territories of Iran.

UPLIFT DEDUCED FROM A PALAEOMAGNETIC STUDY OF NEOPROTEROZOIC DYKES IN CENTRAL SWEDEN

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A palaeomagnetic study has been performed on Neoproterozoic basic dykes in the Fennoscandian shield . Positive contact tests have been demonstrated and on the basis of the data from the baked host rock of one of the dykes the uplift of the present erosion surface is estimated . From the palaeomagnetic results of ten samples of the baked gabbro the ambient temperature at the time of dyke intrusion is determined at 395 C° , with a standard deviation of 16 C° . Assuming a palaeogeothermal gradient of 28 C°/ Km (± 30 %) the estimated depth of burial of the present erosion surface can then be calculated at 12 ± 4 Km . On the basis of the palaeomagnetic data the age of the dyke is ca 1.4 Ga , which means an uplift rate of this part of the Fennoscandian shield of 0.009 Km / Ma .

FAULTING IN MID-OCEAN RIDGES: FORMATION OF ABYSSAL HILLS

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The tectonic plates are formed and move apart at a mid-ocean ridges. Some portion of this plate separation in slow-spreading MORs is thought to occur by stretching, resulting in a complex pattern of normal fault offset. Abyssal hills, the most areally extensive topographic features on Earth, are thought to be a product of this faulting. Here, we report the results of a self-consistent numerical model of lithospheric formation and stretching that includes spontaneous fault creation. An axial valley develops where the fault activity is most concentrated. "Frozen" fault generated topography, rafted out of the axial valley, is visually and statistically simillar to observed abyssal hills formed at many slower-spreading ridges. Since we do not include magmatic crustal accretion and spreading-rate-dependent thermal structures we cannot yet ascess the controls on the amplitude of abyssal hills for the full range of spreading conditions. The model results suggest that the irregularity of abyssal hill relief may result from a self-organized critical stress state at a spreading center. We also propose several mechanisms for explanation of abyssal hills in fast-spreading ridges.

DEEP SEISMIC SOURCES AND CRITICAL TEMPERATURE

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The mechanism of deep earthquakes is still vigorously debated among the researchers. Some pieces of evidence of this geodynamic process can be searched in the comparison of the seismic activity and the thermal structure. The heat-flux pattern reflects lateral variations of structural and mechanical properties of the lithosphere-asthenosphere system. Our analysis of the rheological behaviour is focused on the southern Tyrrhenian area. The seismic activity (maximum frequency of events) is concentrated in the depth interval 200-350 km, and in terms of energy (magnitude) is maximum between 250 and 300 km. Most earthquakes are confined within a 50-70 km thick slab. The slab dip angle is about 65* from 100 to 350 km depth and is well correlated with the total tectonic subsidence and thus with the drag stress of the subducted slab. Below 350 km depth the dip angle decreases down to 500 km depth where the deepest events occur. The focal mechanisms are by down-dip compression. In the hypothesis that the seismic activity is confined to those parts which have a temperature below a depth-dependent critical value, the temperature distribution within the sinking slab was determined by assuming a mantle with an adiabatic temperature gradient. The latent heat of olivine-spinel phase change, resulting in a temperature increase, was taken into account. At the 500 km depth, a 60 km thick slab which sinks at a velocity of 6 cm/yr yields a minimum temperature compatible with the seismic activity.

GEODYNAMIC EVOLUTION OF THE ROMANIAN CARPATHIANS AREA IN THE ALPINE OROGEN

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From structural points of view the Carpathians Orogen belongs to the Alpine period and represents a part of Tethysian - Himalayan belt. Romania comprises Eastern and Southern Carpathians, Apuseni Mountains., with intramontaneous basins (Transylvanian and Pannonian ones) surrounded by the foreland. The geotectonic units are represented by one mobile Alpine region, the Carpathians and Pre-alpine cratons : Moesian, Scythian and Moldavian platforms . The Carpathian area is mainly an Alpine orogen bounded westwards by the Alps and southeastwards by the Balkans. It has a peri-cratonic position, in the southwest of the Eurasian plate, and it is composed of inner units (N. Apuseni Mts.) molded by the external Carpathian arc, which consists of basement and cover nappes and post-tectonic structures. The geodynamic evolution depends on successive cycles of ocean opening and closing. The complete sequence of spreading/compression events, belongs to the Alpine cycle, whereas pre-alpine cycles are represented by parts of their sequences incorporated in the alpine structures. The present-day view of the Carpathians area is associated with the development of the Palaeo-and Neo- Tethys system. Interpretation of the subduction, collision and post-collision events is tried, in the light of sialic blocks, calc-alkaline volcanic rocks position, in correlation with the Tethysian suture of back-arc settings.

SE2 Dynamics, mineral physics and tomographic imaging of the Earth's mantle

Convener: Montagner, J.-P.
Co-Convener: Schmeling, H.

PRELIMINARY RESULTS FROM NONLINEAR GLOBAL TRAVEL-TIME TOMOGRAPHY

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Recent global tomography models, constructed through linearized inversion, by van der Hilst et al. (Nature, 1997) and Zhou (JGR, 1996) show smaller scale mantle structures than had been imaged on a global scale before.
In a similar, but still linear approach we have been able to take their improvement a step further, mapping upper mantle structure with detail (60-100 km) directly comparable with that obtained in high resolution regional studies. This was achieved through the implementation of an accurate global data set and a model parameterization with cells of variable sizes.
To further improve global travel-time tomography we extend the method to nonlinear inversion. Up to now the nonlinear global tomography problem has always been linearized about the ray paths in the 1-D reference Earth model used. The bending of rays due to lateral heterogeneity has not been taken into account, but may be very important when imaging small-scale structure.
We will present results from the linear inversion (focussing on the behaviour of slabs in the transition zone, deep subduction, remnants of past subduction in the lower mantle and the deep roots of hotspots) and first results from nonlinear inversion.

GLOBAL ATTENUATION TOMOGRAPHY FROM FUNDAMENTAL MODE SURFACE WAVE DATA

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We aim to jointly invert phase and amplitude measurements of surface waves between 40 and 150 seconds. To model the main phenomena acting upon the wave amplitudes, we include effects from geometrical spreading, focussing and intrinsic attenuation. The quality factor and phase velocity maps are expanded on a spherical harmonic basis. In a first step, we assume that the source amplitude is known with sufficient accuracy. We introduce focussing effects in the amplitude equation, using the WOODHOUSE and WONG (1986) path integral approximation. We check the validity of this approximation as a function of degree of the spherical harmonic expansion using exact ray tracing on the sphere. Our data set is the same as that of TRAMPERT and WOODHOUSE (1995). Some amplitude data show suprising inconsistencies which could be due to site effects, poor seismic moment determination or incorrect focal mechanisms. In order to quantify these anomalies, we introduce in the inversion, an amplification factor for each station and a seismic moment correction for each event. We present attenuation maps obtained in the period range 40 s-150 s and discuss the source and station amplitude anomalies.

THE ACCOUNT OF THE EARTH'S CHARACTERISTIKS ALONG THE RAY AND THE SECTIONS FOR THE EARTH'S TOMOGRAPHY

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In order to state the forward topographic problem for a 3D spherically symmetric model of the Earth, an algorithm for calculating the varieties in its properties (density, seismic velocities, etc.), revealed by sounding the Earth with parallel rays, is proposed. For a moving radiation source, these properties are considered functions of three variables: the angle of incidence of a ray in a spherical coordinate systems and the two coordinates of the incidence point of the ray on the surface. As an example, the traces of parallel neutrino beams passing through the rotating Earth, along vector r fixed by the angles gamma (latitude) and alpha (longitude). By scanning horizontal (gamma=90 grad), vertical (alpha=const) and conical (gamma=const) slices, the integral density along the slices traces of the ray's paths was calculated, depending on gamma, alpha and the coordinates. The algorithm my be used not only for the neutrino topography, but also for the seismic tomography and Earth's interior, applied with allowance for the regional features of the Earth's surface.

DYNAMICS OF SUPERPLUMES GENERATED BY PHASE TRANSITIONS AND VARIABLE VISCOSITY CONVECTION.

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We have investigated the nonlinear dynamics of superplumes with an axisymmetric spherical model which can handle variable viscosity which depends on temperature, pressure and the location of the moving phase boundary. The interaction of the superplume with the 670 phase boundary gives rise to a large hot region below the phase change, which gives birth to secondary plumes . The non-linear effects associated with the phase change thermodynamics govern the dynamics of the upwelling into the upper mantle. The action of the endothermic spinel to olivine transition dominates in the overall development of the shape, temperature and velocity of the upwelling, as it impinges on the top boundary layer. Thus the phase transitions control directly the interaction between mantle plumes and the lithosphere. Furthermore, the stress fields inside these superplumes reveal a focussing of stress at the base of the core-mantle boundary and at the base the transition zone. Such a distribution of peak stresses may be correlated with the recent findings of seismic anisotropy.

ABOUT THE RAY'S ANGLES FOR THE NEUTRINO TOMOGRAPHY THE EARTH

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The solar neutrino tomography is applied to obtain information about internal structure of the Earth and planet. Variation in the direction of natural neutrino fluxes within the Earth is described by the angles specifying the Earth-Sun vector. It was found that, for each of the detectors installed on the Earth and for the same values of the angles, but at different recording time, the particle beams pass along the same paths within the Earth. The same ray length, Earth's density and other parameters characterize the paths. The flux traces and Earth's parameters are evaluated as a function of three variables - two angles (zenith-angle and hour-angle) and the detector coordinates. Based on the equality of these angles for different moments of time, the events to be obtained in different years as a result of scanning the Earth by solar neutrino may be combined to compile the database for each detector.

THE MODELLING OF IRREGULARITIES OF THE EARTH CRUST IN 3D MATRICE'S SLICES

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The devised algorithm of constructing numerical arrays on the basis of lineament network descriptive of irregularities of the Earth surface gives a three-dimensional distribution of numerical values of specific length of lineaments. This distribution describes the field of tectonic fragmentation of lithosphere. Computer programs for calculating numerical arrays of horizontal, vertical and diagonal slices of 3d matrices, modelling irregularities of the Earth crust, are devised. A method of computation and visual presentation of these arraysis proposed. These results allows fast and reliable finding in a model of Earth crust the sites with strain condition where the centres of high magnitude earthquakes can occur.

GEOID AND DYNAMIC TOPOGRAPHY FOR THE MANTLE WITH A PARTIALLY PERMEABLE BOUNDARY BETWEEN UPPER AND LOWER MANTLE

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The inversions of the long-wavelength geoid in conjunction with the seismic tomographic information have so far been carried out mostly under the assumption of either whole-mantle or perfectly layered circulation. We have tested whether the prediction of the geoid could be improved by including a semi-permeable behavior of the 650-km discontinuity. The permeability of the boundary is changed by imposing a surface density anomaly at a depth of 650 km which is proportional to that which would annihilate the vertical flux across the boundary. In the first step we have assumed that the viscosity varies only with depth. The best fit of the geoid is found if the permeability of the 650-km boundary is reduced to one third of that for the purely whole-mantle model. The resultant viscosity profile is characterized by a clearly defined asthenosphere and a large viscosity increase in the lower mantle. The amplitudes of dynamic topography are remarkably small ($\sim$ 50 m), thus in agreement with the observation. In the next step we have imposed the lateral variations of viscosity (LVV) linked with variations in the lithospheric structure. The inclusion of the LVV does not lead to a significant improvement of the geoid prediction but dramatically influences the flow field in the upper mantle which may be important for the interpretation of the seismic anisotropy data.

COULD THE SLAB-LIKE STRUCTURES FOUND TO EXTEND INTO THE DEEP LOWER MANTLE BE EXPLAINED BY THERMAL COUPLING?

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The question whether the style of convection is whole-mantle or layered has been discussed from many viewpoints. Recently, a strong argument favouring the whole-mantle concept came from the results of seismic tomography when the high resolution models detected the seismically fast slab-like structures extended into the deep lower mantle. This, however, does not necessarily mean, that slabs really penetrate the 660-km boundary. Thermal coupling between the partially or fully separated upper and lower mantle flow systems could be an alternative explanation of the tomographic results. In present study we investigate the possibility that the seismic velocity anomalies found in the lower mantle can be associated with the downwellings induced by the cold slab material lying above the 660-km boundary rather than with the slabs penetrating into the lower mantle. We use a 2-D model of subduction, assume the temperature- and pressure-dependent viscosity and take into account several concepts of viscosity stratification with depth based on the results of recent geoid interpretations. The preliminary results idicate that even if the 660 km boundary is impermeable the flow currents induced in the lower mantle in some models of mantle viscosity stratification could explain tomographic results without the presence of the upper mantle material deeper than 660 km.

"410" AND "660" KM DISCONTINUITY PROPERTIES AND THERMODYNAMIC MODELS.

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Regional arrays of seismometers in the United Kingdom and western United States are used to investigate the properties of the '410' and '660' km seismic mantle discontinuities in western Pacific and South American subduction zones. We enhance weak arrivals between P and sP, caused by interactions with these discontinuites, using slant-stacking. Results from the Izu-Bonin region indicate that the '410' is elevated by 60 km and the '660' depressed by 40 km in the vicinity of cold subducted material. Combined with Clapeyron slope estimates an 800 degree slab-induced thermal anomaly is indicated compared to the mantle at a depth of 350 km. As the '410' moves shallower reflections from it become dimmer indicating a reduction in its' sharpness. The weakest p'410'P arrivals observed originate near the coldest part of the slab. Both the depth and sharpness properties of the discontinuity are consistent with a phase change origin with a positive Clapeyron slope. We compare observed reflection and conversion coefficients with those calculated from thermodynamic models of the olivine to β-modified spinel phase change. Preliminary results indicate that these seismological observations are larger than the thermodynamic modelling suggests. Water concentration may also affect '410' sharpness, since H_2O strongly prefers the β-phase to olivine, broadening the transition. Our results suggest that no more than 400 ppm water is present at this depth.

ANISOTROPY OF HETEROGENEITY SCALE LENGTHS IN THE LOWER MANTLE

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High frequency precursors to PKIKP, scattered by statistical models of D" heterogeneity, are computed by applying standard and generalized Born approximations with elastic Green's functions computed by dynamic ray tracing and summation of Gaussian beams. Heterogeneity having either an isotropic or an anisotropic distribution of scale lengths can fit the observed coda shapes and decay rates with distance of PKIKP precursors. PKIKP precursors constrain the power of the heterospectrum to D" to have 1 to 3% perturbation in P velocity in the horizontal direction for scale lengths on the order of 20 km. The vertical scale lengths of heterogeneity, however, can have significant power at lengths as large as 200 km and still be consistent with most precursor data. Both isotropic and anisotropic models of the distribution of scale lengths have heterogeneity extending up to 1000 km above the core-mantle boundary. The anisotropic distribution of scale lengths, with longer vertical than horizontal scale lengths, predicts slightly lower frequency content for PKIKP precursors than the isotropic model. This model also predicts transverse isotropy of long period shear waves traversing D" such that SV is faster than SH in all azimuths. These predictions can be exploited to detect regional variations in the statistics of the heterospectrum of D" heterogeneity.

DYNAMICS AND FATE OF A STRATIFIED MANTLE: MIXING AND HOT SPOTS

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Both geochemical and sismological data show that the mantle is heterogeneous in density on very different lengthscales.To better understand the influence of those heterogeneities on the convective regime of the Mantle, we investigate the mixing and thermal pattern resulting from thermal convection in two superposed layers of miscible fluids, using laboratory experiments. Rayleigh numbers between 300 and 4.10^7 were obtained for initial density ratios between 0.45 and 5 %, viscosity ratios between 1 and 6.10^4, and depth ratios between 1 and 10. Quantitative measurements of heat flux and mass flux were made and scaling laws derived.
Motions occur on two scales: (1) small-scale thermal instabilities originating at the outer boundaries are modulated by (2) a large-scale circulation generated at the interface through the interaction of lateral thermal heterogeneities and the chemical density gradient. Entrainment occurs only through (2): the most viscous layer entrains cold sheets of less viscous fluid, creating a pattern of 3 D cells while the entrainment in the less viscous fluid occurs through cylindrical narrow and hot plumes centered on each cell.Such a stratification in the Mantle would last for more than 40.10^8, and the interface would move down. The lower reservoir would contribute to between 1 and 15 % of each hot spot mass flux.

FORMATION OF A METASTABLE OLIVINE WEDGE IN A SUBDUCTING SLAB

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We present a thermal model of a descending slab in which the reaction of olivine to spinel is controlled by pressure- and temperature-dependent kinetics. We use a finite element method to solve the coupled heat conduction and kinetics equations, and we include the latent heat of the transformation. Latent heat release together with heat conduction reduces significantly the length of the metastable olivine wedge and results in a very thin (< 5 km) two-phase region. We employ the thermal parameter of the slab to interpret the results for the length of the wedge . If the occurrence of deep earthquakes is related to the transformation of metastable olivine to spinel, then data on earthquake depth versus thermal parameter require that the onset of the reaction takes place at temperatures of about 550° – 575°C. In this case the slab thermal parameter must be larger than 10,000 km for the metastable olivine wedge to extend down to 660 km depth. But deep earthquakes occur near 660 km depth in slabs with thermal parameter as small as about 5000 km (South America, for example). Either some deep earthquakes are unrelated to olivine metastability or our knowledge of olivine-spinel reaction kinetics is incomplete. Using a viscoplastic rheology, the strain and stress inside the slab are also computed. Down dip compression is found inside the wedge.

SEISMIC VELOCITY, TEMPERATURE AND COMPOSITION: THE MENDOCINO TRIPLE JUNCTION AREA

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In the context of the NEESDI program we started an effort to invert tomographic images of P- and S-wave velocities for temperature and composition of the uppermost mantle. As a first step we perform forward modeling of P-wave velocity anomalies (Benz et al. 1992) below the Mendocino Triple Junction (MTJ) area in northern California, where independent information on the thermal structure is available from three-dimensional modeling based on the kinematic evolution of the triple junction (Goes et al., 1997).
At the northwestward migrating MTJ subduction of the Juan de Fuca plate beneath North America gets replaced by transform motion along the San Andreas fault system. Well documented kinematics for this area predict a pronounced thermal signature as the lithospheric "window" left behind the subducting slab is filled with warm asthenosphere. Anomalies in heatflow and seismic velocities have been attributed to this warm shallow slab window. Preliminary forward modeling results indicate that temperature alone yields anomalies with longer wavelength and smaller amplitude than those obtained from seismic tomography. We investigate whether incorporating the effect of composition for the oceanic lithosphere, the slab window and the continental lithosphere results in a better agreement with the observed velocities.

SE2

HEAT TRANSFER AT THE BASE OF THE LITHOSPHERE FOR A NEWTONIAN AND NON-NEWTONIAN, HIGHLY TEMPERATURE AND PRESSURE DEPENDENT RHEOLOGY

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A numerical model of bottom-heated, two-dimensional convection is used to study, in Newtonian and non-Newtonian rheology, the relationship between the surface heat flow number and the viscosity at the base of the lithosphere. We find, for both cases, a law of the following form : $Nu \propto Ra_{BL}^{1/3} \delta T_{eff}^{4/3}$, where δT_{eff} is the temperature jump in the destabilised part of the lithosphere. δT_{eff} contains a corrective term which takes into account the pressure-dependence of the viscosity.
The law above is not valid for low heat flow cases. For $\Phi < 4$ with a Newtonian rheology, and $\Phi < 2.5$ with a Non-Newtonian rheology, the exponent of the Rayleigh number is close to 0.2 as predicted by the boundary layer theory.
The predicted heat flow are the same for Newtonian and non-Newtonian cases if the activation energy in the non-Newtonian case is twice the one in the Newtonian case.
With this law, we can have an estimation of the viscosity at the base of the stable oceanic lithosphere. If the surface heat flux due to the secondary convection is of 40 to 50 mW.m^{-2}, the viscosity is predicted to be between 1.62.10^{18} and 3.66.10^{18} Pa.s.

A NUMERICAL STUDY OF THE DYNAMICS OF SUBDUCTING SLABS AND TRANSPORT OF MELT THROUGH THE MANTLE WEDGE

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Geochemical evidence from ^{10}Be measurements indicates that material from the downgoing slab is erupted within a relatively short time after being subducted (8-10 Ma). This indicates that melted material from the subducting slab is not migrating vertically towards the surface in a simple stokes-flow pattern. The melt must migrate much more rapidly from the slab to the surface in order to satisfy the geochemical evidence. Melt may migrate rapidly if it flows through a porous network of interconnected channels or if it lowers the overall viscosity of the mantle. To explore how melt is transported through the mantle wedge we have formulated a thermal convection model which solves Stockes equation in a subduction zone. Velocity field is computed using a penalty function finite element formulation with direct inversion solver. Temperature field is determined with a Smolarckiewicz scheme. Rheology is highly temperature dependent so that the slab maintains its rigidity compared to the mantle even when the slab approaches the suronding mantle temperature. Incorporating tracers into our model will allow us to examine the timescale for material to descend with the slab and return to the surface with the melt. We will also incorporate a seismic model to analyze the velocity structure as it depends upon the pressure, temperature and presence of melt.

INFLUENCE OF PLATE KINEMATICS, CONVECTION INTENSITY, AND SUBDUCTION GEOMETRY ON EARTH'S UPPER MANTLE DYNAMICS

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This study reports results of a 2D numerical mantle convection model that accounts for the rigidity, movement and geometry of a subducting plate by prescribing particular kinematic boundary conditions. For Rayleigh numbers in the range 1.2×10^4-6×10^5, a motionless overriding plate, subduction dip angles of 70°, 45°, and 30°, and subduction velocities in the range 0.3-10 cm/yr, we precise the interactions of the subducting plate as well as the overriding one with the underlying mantle. First, the circulation may be either steady or unsteady. In the latter case, only obtained for subduction dip angles greater than 30°, we observe instabilities that affect both horizontal thermal boundary layers under the moving plate and only the upper thermal boundary layer under the motionless overriding plate. Then, below the moving plate and for angles greater than 30°, we find as previous studies with free subduction that the greater the convection intensity, the greater the plate velocity is required to obtain a steady monocellular pattern, traducing the dynamical mantle plate-coupling. This is not characteristic of an angle of 30° because the downgoing plate has a strongly stabilising influence. Below the motionless overriding plate, it is predicted a surprising single-cell circulation under this plate for a sufficient convection intensity. This monocellular pattern is obtained for a smaller subducting plate velocity as the subduction dip angle is smaller. Correlations with surface observables as back-arc stress states are discussed.

NORMAL-MODE CONSTRAINTS ON MANTLE STRUCTURE

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The sensitivity of the Earth's normal modes to lateral heterogeneity may be expressed in terms of 'splitting functions' or 'interaction coefficients' which represent a 2-D radial average of the mantle's 3-D heterogeneity. Recently, a large number of splitting-function coefficients has become available through analysis of seismograms recorded after several large earthquakes in 1994–1996. These include splitting-function coefficients of toroidal modes and of cross-coupled modes, some of which are sensitive to the odd degree heterogeneity. We are using these new, improved sets of splitting-function coefficients to recover, in addition to shear speed perturbations, even and odd degree lateral variations in bulk sound speed, density, and topography on internal discontinuities. Of particular interest are the scaling relations between bulk sound and shear speed, and between density and shear speed.

HEAT CELLS AND MANTLE CONVECTION

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The experimental study of temperature and heat flow anomalies was made on the East European platform. We made temperature measurements in 572 deep boreholes which had a steady temperature regime. The research results convince us that there is the spatial periodical pattern of terrestrial heat flow. Our experiments have revealed large positive heat flow anomalies surrounded by zones of low heat flow (heat cells). They have characteristic sizes of the order 300 to 750 km. The model of small-scale convective flows in the mantle well agrees with these data. The observed heat flow anomalies can be explained by the existence of convection cells with upwelling centers. For example, these are the Central-Russian, Precaucasus, and Greater Caucasus cells. The cells are characterized by an extensive ascending region, isolated descending stripes with small areas extent, and narrow transition zones with rapidly varying heat flow. Numerical modeling is used to investigate the processes leading to the observed heat flows. The best coincidence between theoretical and measured temperatures and heat flows is observed when the lower boundary condition at the asthenosphere top is given in a form of the temperature distribution corresponding to a hexagonal convection cell in the mantle. It might therefore be concluded that the heat flow distribution itself offers a direct view of mantle convection revealing the geometry of flows, its vigor, spatial sizes and interrelation of cells. Our results also provide a simple explanation for the heat flow distribution in spreading zones. Thermal models predict the existence of a small-scale cellular convection beneath mid -ocean ridges.

SURFACE-WAVE POLARIZATION TOMOGRAPHY

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In order to better constrain upper mantle lateral heterogeneity, we have collected and analyzed observations of surface wave phase and arrival angle in the period range 125 to 35 seconds. Arrival angle measurements are only attempted on seismograms for which phase dispersion was previously measured accurately. We have created a database of about 9,000 Rayleigh and 13,000 Love wave arrival-angle measurements. The new observations are interpreted in terms of station misorientation and global phase velocity structure. We find that several stations have horizontal components for which the orientation has been incorrectly reported. The misorientation of stations can be as large as 10° and explains a significant amount of the signal in the data. At this stage, our results show at least 16 stations are misoriented. After removing these station corrections, we interpret the measurements in terms of lateral variations in phase velocity. We invert the arrival-angle measurements to obtain maps of phase velocity which correlate well with maps derived from surface-wave phase measurements. We then combine the phase and arrival-angle measurements to obtain models which satisfy both data sets. We have compared these models to regional studies where they exist, and often see similar features. Our models, however, are global and thus provide insight into the structure of regions of the upper mantle which are inaccessible by other means.

LITHOSPHERIC AND ASTHENOSPHERIC STRUCTURE OF THE INDIAN OCEAN FROM A WAVEFORM TOMOGRAPHY

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The upper mantle structure of the Indian Ocean is studied by a tomographic method based on a waveform inversion of surface wave seismograms. The waveform modelling allows to build an average model for the epicenter-to-station path, accounting simultaneously for several seismograms related to that path. Love and Rayleigh wave seismograms for earthquakes at different depths in a same epicentral region are used for this purpose. The inverted parameters are primarily the S-velocity, the ξ anisotropic parameter and the S-wave attenuation factor Q_β^{-1} as functions of depth. The path-averaged structural parameters obtained from the waveform inversion are then turned into a 3-D structure through a tomographic method, namely a continuous regionalization performed at each depth. In this tomographic stage, the azimuthal anisotropy pattern can be retrieved in addition to the S-velocity 3-D structure. While most features observed on the S-velocity and on the S-anisotropy are in good agreement with what is expected from tectonics (low velocities beneath the ridges, fast anisotropic direction parallel to the plate motion). exceptions exist. like a high velocity zone at shallow depth beneath a small part of the East Indian ridge and a drastic change in the fast anisotropic direction beneath Australia at 150-200 km depth. Results on the attenuation structure, more difficult to obtain and to validate, will be also discussed.

SOME TESTS ON THE REFLEXION AND TRANSMISSION PROPERTIES OF THE 660 KM SEISMIC DISCONTINUITY

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In a recent paper, Vacher et al. proposed that transformations of the non-olivine components of mantle mineralogy could significantly influence the amplitude of the 660 km seismic discontinuity, whatever the style of mantle convection relevant to a given location in the Earth's mantle (i.e. stratified or whole-mantle convection). In particular, mineralogical transformations in the garnet-ilmenite-perovskite system could lead to a multiple-step transition from the upper to the lower mantle in cold regions of the mantle, in addition to the discontinuity induced either by the thermal boundary layer separating the lower mantle from the upper mantle (stratified convection) or by the γ-spinel to Mg-perovskite and magnesiowüstite reaction (whole mantle convection). These conclusions were drawn after a direct comparison between theoretical amplitudes of seismic discontinuities computed using mineral physics data, and the observed strengths of the 660 km discontinuity in different one-dimensional seismic models. Here, the reflexion and transmission properties of the theoretical seismic discontinuities are computed in order (1) to test how efficiently they can be sampled by seismic waves, and (2) to determine the type of waves, the domain of epicentral distances, and the seismic frequency range which would be most useful to evidence them as accurately as possible.

ONSET OF CONVECTION IN BINARY FLUIDS WITH TEMPERATURE-DEPENDENT VISCOSITY

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We consider an infinite horizontal binary fluid layer with infite Prandtl number heated from below. The onset of Rayleigh-Benard convection is investigated in the case of a temperature-dependent viscosity. On the horizontal boundaries which are rigid, the temperature and concentration values are fixed. A linear stability analysis is performed using a perturbation method based on a Fourrier expansion on the x-axis and a Tchebychev polynomial expansion on the y-axis. We determine at Le=0 (Le=Lewis number) how the viscosity and the separation ratios influence the critical parameters which quantify the onset of the convection (Rayleigh number, wave number, frequency). We show that the approximations, regularly used for these critical values at constant viscosity, are only valid for values of the separation ratio between -0.8 and 0.We extend the theory of convection in sublayer well known for monocomponent fluids with strongly temperature-dependent viscosity to binary fluids.

In a frame with Lewis number on the x-axis and separation ratio on the y-axis, the critical Rayleigh number reaches a maximum and the critical wave number becomes constant when convection goes from oscillatory to stationary.

EFFECTS OF MANTLE FLOW ON THE ORIENTATION, DISTRIBUTION AND MOTION OF PLUMES AND SLABS

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We construct models of mantle flow based on density heterogeneities inferred from seismic tomography and plate geometry and motions to study the transport of plumes and subducted material in the mantle. The models incorporate the history of plate motions over the last ~100 My and advect the density field over the same time. Plumes are
modelled as initially vertical buoyant conduits that are tilted by the flow. Subducted material is modelled as density elements that sink as they are advected by mantle flow.

The observed distribution of plumes is similar to an initially random distribution that is organized by large scale mantle flow. Plume sources on the CMB are displaced from hotspots by several degrees. The source of Hawaii is SE of the hotspot: the sources of Kerguelen, Reunion and Tristan are closer to southern Africa than are the hotspots.

Slabs sink into the lower mantle, and are displaced laterally by hundreds of kilometers. The models exhibit an increase of viscosity with depth in the lower mantle, and a low viscosity upper mantle, similar to other models. These models provide a link between seismic tomography and seismic observations of plumes and slabs as well as geologic observations of hotspots and plate tectonics.

FROM ACH TELESEISMIC TOMOGRAPHY TO ABSOLUTE VELOCITY

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A popular method for 3-D seismic imaging of the Earth's structure is the ACH method named after Aki et al. (1977). This method is characterised by the use of relative residuals, in order to avoid biases coming from errors on the hypocentre location and on the origine time of the event. and also from the differences between the actual Earth structure and the 1-D reference model used outside the target volume. As a consequence, the ACH method do not really retrieve the 3-D structure of the target volume, but instead provides velocity contrasts relative to the layer-average of the velocity, this average value remaining unknown. This particularity of the method impairs the interpretation of ACH tomographies in two ways. First the velocity contrast are known only in the horizontal direction. Vertical cross-sections can therefore be meaningless. Second the unknown layer-average velocities act as free parameters and can easily transform a negative contrast. for example. into a high velocity zone. A way to avoid these two problems is to get knowledge on the 1-D average model for the target volume from independent data. In this paper. we examine on synthetic data how the knowledge of the average 1-D model for the target volume can improve the interpretation of ACH results. We then construct an absolute 3-D velocity model for northern Tibet by combining the results of an ACH study with a regional 1-D model derived from a global surface wave study.

EQUATION OF STATE OF MAGNESIOWUESTITE AND WUESTITE

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Equation of state (EOS) of magnesiowuestite (0.6Mg,0.4Fe)O is determined by the potential method, using the X-ray data by Y.Fei et al. (1992) at pressures to 30 GPa and temperatures to 800 K. The use of the high- temperature X-ray data significantly improves the fitted EOS. The least- squares fit yields the following values at ambient conditions: the adiabatic bulk modulus K = 159 GPa, its pressure derivative K'= 3.9, the isothermal and adiabatic Anderson-Gruneisen parameters deltaT = 4.7 and deltaS = 2.0, respectively, the volume expansivity alpha = 3.4E-5, the Debye temperature is 600 K, and the Gruneisen gamma is 1.5. For P = 0 and T = 1700K, we found K = 127 GPa, K'= 4.0, deltaT = 3.3, deltaS = 1.8, and alpha = 4.8E-5; and for P = 24 GPa and T = 1900 K, we have K = 230 GPa, K'= 3.5, deltaT = 2.9, deltaS = 1.4, and alpha = 3.3E-5. The EOS' of magnesiowuestite and periclase and the volume additivity condition were used to determine the EOS of wuestite. The EOS' obtained are suitable for the analysis of the lower mantle composition.

SE2

PHASE DIAGRAMS OF THE MANTLE MINERAL SYSTEMS AND THE MANTLE TRANSITION ZONE

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The phase relationships and complete phase diagrams of the systems $MgO - SiO_2 FeO - SiO_2$, $Mg_2SiO_4 - Fe_2SiO_4$, $MgSiO_3 - FeSiO_3$, and $MgO - FeO - SiO_2$ are calculated with the help of the Gibbs energies determined by the potential method in a pressure-temperature range of up to 25 GPa and 2500 K. The phases involved in the computation are quartz, coesite, stishovite, olivine, two spinels, pyroxene, ilmenite, perovskite, and garnet. The Gibbs energies of the imaginary phases in the $FeO - SiO_2$ system were constructed by using various constraints on their volume, metastability. the Fe content in the phases, topology of the phase diagram fragments, etc. The P-T diagrams and the phase compositions were computed by direct minimization of the Gibbs energy, using an algorithm by C. De Capitani and T.H. Brown (1987). These results are used to discuss the seismic structure and mineral composition of the mantle transition zone at depths from 400 to 700 km. The sequence and depths of the phase transitions in this zone greatly depend on the bulk compositions. adopted geotherm, and the properties of the imaginary phases.

THE UPPER MANTLE UNDER THE TYRRHENIAN SEA FROM A BROAD-BAND STUDY OF DEEP EARTHQUAKES

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We studied deep earthquakes under the Tyrrhenian Sea recorded at Mednet and other broad-band stations around the Mediterranean Sea. These events are very suitable for studies of the upper-mantle under the Tyrrhenian sea. After constraining the mechanisms and depths of these events, we modelled the broad-band displacement waveforms using ray techniques. We find low velocities under the Tyrrhenian Sea compared to the surrounding regions, and because of the broad-band character of the recordings we have been able to determine both Poisson's ratios as well as P and S wave attenuation. This provides some good constraints on the mineralogy of the upper-mantle in this region. These broad-band recordings also put good constraints on the depth of the 400 km upper mantle discontinuity, both under the Tyrrhenian Sea as well as under the surrounding regions, and we will present an interpretation of these results in terms of upper-mantle mineralogy and dynamic processes

PHASE TRANSITIONS IN THE UPPER MANTLE

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A detailed thermodynamic study of the transition zone seems to be crucial for understanding the mantle dynamics. Due to the Clapeyron slope the phase transitions occur at different depths in hot and cold areas. Various papers have indicated that the arising buoyancy forces can affect the ability of subducting slabs or hotspot plumes to penetrate the 670 km boundary. However, this effect has only been modeled assuming univariant transitions or transitions in a pure olivine mantle. Therefore, we have studied the phase transitions in the realistic model of mantle composition involving the non-olivine content. We computed the equilibrium mineralogical composition of the mantle Mg-Fe-Al-Ca-Si system by using a numerical code based on the free-energy minimization. We used these results for computing the corresponding mantle density profiles. We have also computed the density excess arising from temperature variations inside subducting slabs and hotspot plumes. The amplitudes of density jumps related to different phase transitions are temperature dependent and, thus, have different dynamic effects for cold slabs and hotspots plumes. We will discuss the dynamic implications of the sum of the various phase transitions. We will show that a slight advection by the flow of the equilibrium boundary due to latent heat buffering or to kinetics delay can have an important geophysical effect by reducing the dynamic topography associated with the internal masses.

TEMPERATURE, PRESSURE AND COMPOSITIONAL DERIVATIVES OF SEISMIC VELOCITIES WITH APPLICATION TO THE LOWER MANTLE

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We compute here the partial derivatives of seismic velocities with respect to temperature T, pressure P and composition X, using a Birch-Murnaghan equation of state and finite strain theory. We consider two minerals, perovskite and Mg-wüstite, and the X variable is the volume proportion of perovskite. Single mineral properties are Voigt-Reuss-Hill (VRH) averaged. The VRH formulae are then differentiated with respect to T,P and X to give the expressions for the partial derivatives. Large ranges of variation of input parameters are considered: surface temperature, pressure profile, proportion of perovskite, iron content and partitioning, and elastic parameters determined from laboratory measurements. T- and P-derivatives are nearly independent of the input parameters, but X-derivatives can vary by 50% with realistic variations on the iron content or partitioning. At a depth of 2000 km, the T, P, X derivatives are such that a 1% seismic anomaly of P-waves can be explained either by a temperature difference of 300 K, a pressure anomaly of 3% with respect to PREM, or a perovskite content variation of 5-15%. We are currently inverting P- and S-wave velocity models of the lower mantle using these derivatives for different values of iron content and partitioning.

PHASE TRANSITION MODULATED MANTLE CONVECTION WITH PRESSURE AND TEMPERATURE DEPENDENT RHEOLOGY: IMPLICATIONS FOR THE RADIAL VISCOSITY STRUCTURE IN THE EARTH

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What is the the form of the radial viscosity profile near the 660 km endothermic phase transition in Earth's mantle? In order to address any question regarding the radial structure of mantle physical properties, such as viscosity, we require a clear understanding of the interaction between a convecting mantle and the minerological phase transitions that exist at depths of 410 and 660 km. This interaction is complicated by the fact that the viscosity of mantle materials is strongly temperature and pressure dependent and so any attempt to answer this question must account for such influences. We will employ a time dependent, axi-symmetric spherical convection model which incorporates both temperature and pressure dependent rheology as well as the influence of both the endothermic and exothermic phase transitions in an attempt to address this issue. Results obtained from appropriately designed numerical simulations will be employed to explore the details of the flow patterns and of the viscosity structure near the 660 km interface. We attempt to reconcile this information with current understanding of the radial viscosity profile derived by inversion of appropriate data sets.

CONSTRAINTS ON THE STRUCTURE OF THE UPPER MANTLE BENEATH AUSTRALIA FROM WAVEFORM TOMOGRAPHY

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One of the primary objectives of the SKIPPY seismometry project (Van der Hilst et al., EOS, 1994) is the delineation of three dimensional variations in seismic wavespeed beneath Australia by exploiting the wealth of natural sources along the plate boundaries surrounding the continent. The structure of the upper mantle beneath eastern Australia is well constrained by broadband data recorded at the SKIPPY stations but in order to improve data coverage in western Australia we have augmented the SKIPPY data set by waveforms from 7 instruments of the Australian National Network operated by the Australian Geological Survey Organization. We further improved the waveform modelling by using estimates on crustal thickness from receiver functions (Shibutani et al., GRL, 1996) and by using previous estimates of 3D structure (e.g., Zielhuis & Van der Hilst, GJI, 1996) to update the reference models and the sensitivity kernels (mode files) for the Partitioned Waveform Inversion (Nolet, JGR, 1990).

We present our new model for the Australian continental mantle along with various measures of model uncertainty, and we discuss the correlation with the gravity field. The new results confirm previous indications that the eastern edge of the central Proterozoic cratons extend significantly farther eastward than previously thought (which concurs with age determinations from mantle xenoliths) and that the upper mantle beneath eastern Australia is very complex. We discuss implications for the interpretation of seismic anisotropy and the Phanerozoic evolution of eastern Australia. Deep continental keels are detected beneath parts of the Proterozoic cratons, but they are smaller in size than expected from surface outcrop. Interestingly, the Kimberly block seems distinct from the surrounding Precambrian basement blocks and the Archean and Proterozoic units of west and central Australia, respectively, are separated by a deep 'trough' of relative low wavespeeds.

ASPHERICAL STRUCTURE OF EARTH'S LOWER MANTLE

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The relationship between structural heterogeneity just above the core mantle boundary (CMB) and dynamic processes in the overlying mantle is still enigmatic. Differential travel time techniques zoom in on structure in the CMB region by effectively suppressing signal from shallower depth. As a corollary, these studies do not constrain the connection between the thermal boundary layer and the rest of the mantle. Imaging of deep mantle structure based on spherical harmonics gives more insight in this problem by constraining radial variations in heterogeneity spectrum and the correlation between *P*- and *S*-wavespeed. Tomographic imaging based on carefully processed travel time data and a cellular representation of structure now begins to resolve sheet-like downwellings in the mid mantle (van der Hilst et al., Nature, 1997; Grand et al., GSA Today, 1997). This allows a more definitive study of deep mantle structure, but data coverage has been a problem. To enhance resolution of lower mantle structure we have augmented the routinely processed *P* and *pP* data with high quality, waveform derived *PP*, *PKP*, and *Pdiff* differential times. The new model confirms a dramatic change from the subduction related planform of heterogeneity that persists to about 1800 km depth to the long wavelength structures in the lowermost 500 km of the mantle. This coincides with changes in the power spectrum and is only partly explained by the fact that downwellings simply must spread out atop the CMB. Not all mid-mantle anomalies connect smoothly to CMB structure, and variations in bulk and shear moduli argue against a purely thermal origin of the anomalies and suggest chemical heterogeneity in the bottom 800 km of the mantle (Su and Dziewonski, PEPI, 1997; Kennett et al., JGR, 1998). These observations indicate that the transition from mid- to lower mantle structure is more complex than previously thought.

THE FATE OF YOUNG SUBDUCTING LITHOSPHERE

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The dynamics of the subduction of young lithosphere is distinct from Benioff-type subduction due to the absent driving body forces within the subducting plate. Subduction of this type is therefore rather passive and the term 'lithospheric doubling' has been coined. This type of subduction has been taking place at parts of the west coast of the Americas (C.Peru, S.Chile, U.S.A) and has been important in the geological history of the Earth. Geological consequences, such as the uplift of the Colorado plateau are recognized.
A 2-D numerical model is used to study the subduction of a compositionally layered young oceanic lithosphere by an overriding continent, driven by an imposed relative velocity of the continental lithosphere with respect to the mantle below. A Newtonian temperature and pressure dependent viscosity is used. Our model results of this lithospheric doubling scenario show, that the rheology of the uppermost layer of a horizontally subducting plate (sediment/basalt) is important due to the large contact zone between the plates. A weak top layer (e.g. due to hydration) has been used as an effective lubricate for the subduction process. This lubricating effect, together with the thickness of the overriding lithosphere and the major phase transitions may strongly affect the dynamics of the subduction process and the fate of the subducting oceanic lithosphere, resulting in fragmented parts of oceanic lithosphere in the transition zone, which may have been detected in seismic tomography results.

THE INFLUENCE OF SURFACE TEMPERATURE ON PLANETARY CONVECTION WITH PHASE TRANSITIONS

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We used a finite element model to study the influence of surface temperature on planetary convection with phase transitions. Non-dimensional surface temperatures (T_0) of 0.2 and 1.2 were chosen to simulate the conditions for Earth and Venus, respectively. Both base and internally heated flows were considered. The main differences between low- and high-T_0 were found to be :
1) The flow structure is much more complex and the upper mantle is much more active for low T_0.
2) In both cases the flow structure is a mixture between layered and whole mantle convection, and the amount of layering is similar, although slightly higher in the low-T_0 case.
3) During events of high mass exchange from upper to lower mantle, the return flow from lower to upper mantle is shallow at low T_0, whereas there are continuous plumes from CMB to the surface and vice versa at high T_0.
We think that besides of differences in rheology the different surface temperatures of Earth and Venus may contribute to different convective platforms in the two planets. These platforms may also have a strong influence on planetary geochemical development.

A NEW CONVECTION-SEGREGATION MODEL EXPLAINING THE ORIGIN OF THE PRINCIPAL GEOCHEMICAL RESERVOIRS OF THE EARTH'S MANTLE

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The thermal and chemical evolution of the Earth's mantle and crust has been modeled simultaneously by a segregation mechanism plus 2D-FD Boussinesq thermal convection. In contrast with the published model K1 [U. Walzer & R. Hendel, Geophys. J. Int. 130 (1997) 303-325; geological interpretation: U. Walzer & R. Hendel, Physics Earth Planet. Interiors 100 (1997) 167-188], layered convection is *not* an assumption but the mineral phase changes are introduced for 410 and 660 km depth using customary values of the Clapeyron slope, the density contrast etc. So we have heat heat sources and sinks at 410 and 660 km, respectively, in addition to the usual Rayleigh number Rq for internal heating by radioactivity and bottom heating at the core-mantle boundary. The viscosity is a function of the temperature field and the pressure. Segregation takes place if the asthenospheric viscosity falls below a certain threshold. Oceanic plateaus, enriched in incompatible elements, develop leaving behind depleted parts of the upper mantle. The resulting inhomogeneous heat-source distribution generates a first feed-back mechanism. A growing continent is produced by accretion and further segregation, consuming the older oceanic plateaus. The lateral movability of the growing continent causes a second feed-back mechanism. The mentioned mechanisms generate acceptable distributions of the convective vigor and of the growth of juvenile continent material over the time axis. These distributions are stable for a moderate variation of the parameters only. The solutions of the system of differential equations show acceptable values for the distributions of the temperature, viscosity, heat flow, mantle-creep velocity and the continent's velocity. The following new result is insensitive to a strong variation of Rq: After an initially rather complex mixing process of the depleted parts and the pristine parts of the mantle, we arrive at a mainly depleted upper half of the mantle including the uppermost parts of the lower mantle and a predominantly pristine lower half of the mantle in the Phanerozoic at the latest. There is no sharp interface between the halves.

SE3 Seismology and physics of the Earth's core and mantle

Convener: Kind, R.
Co-Conveners: Jacob, A.W.B.; Weber, M.

DISTRIBUTION OF STRESS DROP IN AND AROUND TURKEY

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Distribution of stress drop ($\Delta\sigma$) of 413 shallow earthquakes that occurred in and around Turkey during the period 1939-1996 is investigated. The earthquake data with surface wave magnitude $M_S>5.0$ suggests that $\log M_O=1.33M_S+17.32$ (M_O=seismic moment). Using an empirical relation between M_O, M_S and $\Delta\sigma$, an average stress drop is found to be 26.2 bars for all events while different values are obtained for different type of faulting. Smaller values are associated with thrust faults, and higher values represent strike-slip faults. For the events of which $M_S>m_b$ (m_b=body wave magnitude) the average stress drop is 41.2 bars while the events with $m_b>M_S$ present a stress drop of 13.5 bars. Statistical classification of earthquakes in terms of simplicity and complexity introduces a stress drop of 54.4 bars for complex and 7.5 bars for simple events. It is observed that most of the complex events (%67) are associated with strike-slip faults and simple events (%62) are from thrust faults.

TOPOGRAPHY OF MANTLE DISCONTINUITIES

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Vinnik (*Phys. Earth Planet. Inter.*, *15*, 39–45, 1977) introduced a stacking method to enhance weak $P - SV$ conversions from mantle discontinuities at 410 and 660 km depth based on the assumption of plane interfaces. In areas of strong lateral variations of mantle temperature this assumption may not be valid. The olivine-to-β-phase transition (and hence, the "410-km discontinuity") may be strongly distorted in cold subducting slabs of lithosphere as a result of the pressure-temperature dependence of the transition and slab dynamics. The effect of topography on the "410-km discontinuity" on the seismic wavefield is modelled by synthetic reflectivity seismograms. The seismic wavefield from an earthquake source is first calculated for a network of seismic stations. Superimposed on these "initial" seismograms are seismograms from point sources located at the depths that trace the assumed undulations of the "410-km discontinuity" and that model the scattered wavefield from the discontinuity. Discontinuity topography can be retrieved by stacking along travel time curves of diffracted waves rather than assuming refraction through a plane interface.

MODEL STUDIES OF SUB-OCEANIC Po AND So WAVES AND THEIR FREQUENCY DEPENDENCE OF Q

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Long range and high frequency Po and So waves are typical of the world's oceans. Amplitudes rise to a maximum and fall back to background level producing a long coda. Normal mode solution and the synthetic seismogram technique is applied. Frequency dependence of Q is not needed, if only, to simulate the long coda duration and the scattering mechanism is not the main cause of the long coda, although not excluded totally. Constant Q assumption in each layer does not match the observational spectrograms, frequency dependence of Q and the time domain amplitude envelope. Q increasing with frequency provides the desired simulation. The frequency dependence also increases with increasing depth in the lithosphere. For the Po waves, the amplitudes show more the observational form with increasing epicentral distance. Normally refracted and upgoing P waves and their water layer multiple reflections produce the Po coda. Low Q in the upper lithosphere and also P to S conversions make the Po wave energy mainly high frequency at long ranges. The So waves are the result of higher shear mode propagation. A stationary phase at about 4.7 km/sec. in group velocity curves marks the beginning of So waves. Increasing focal depth reduces temporal So amplitudes, while this effect for Po waves is not as strong as So waves. On the other hand, spectrograms still match the observations. For deeper sources temporal Po amplitudes and for shallow ones So amplitudes are dominant, respectively.

INTER-SEISMIC AND CO-SEISMIC DISPLACEMENTS IN GPS SERIES ACROSS THE NEW HEBRIDES SUBDUCTION ZONE.

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The New Hebrides subduction zone is part of the complex converging boundary between the Pacific and Australian plates. This fast (5-15 cm/yr) convergence zone which frequently undergoes Ms > 7 earthquakes is particularly well suited for the detection of inter-seismic strain accumulation. We have selected three characteristic earthquakes (a thrust event of Ms = 7.0 in February 1994 at the interplate boundary, a strike slip event of Ms = 7.4 in July 1994 within the upper plate sheared because of variable plate couplings and a normal faulting event of Ms = 7.9 on the bulge of the subducting plate in May 1995) for which we have modelled the short term co-seismic offsets (dislocation models) and simulated the long-term inter-seismic accumulation of deformation. Comparison between the simulated co-seismic steps and interseismic drift anomalies and the GPS series collected in the vicinity of each event between 1990 and 1997 are presented.

CRUSTAL STRUCTURE IN AND AROUND THE EASTERN TURKEY FROM SINGLE STATION RAYLEIGH WAVE OBSERVATIONS

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The crustal structure is determined from single station fundamental-mode Rayleigh wave group velocity measurements. The earthquakes at regional distances are recorded on a digital broad-band three component and an analog LP vertical component seismographs at TBZ, Trabzon, Turkey. The group velocities are obtained by using the multiple-filter method. Spectral amplitudes associated with the fundamental mode can be seperated from higher modes. In order to determine the crustal velocity model for the studied area, we used an inversion program. That program inverts the observed group velocities for a plane-layered shear velocity structure, and uses singular value decomposition. Poisson's ratio is taken as 0.25 for all inversions and densities are calculated using known relations between density and compressional-wave velocity in the crust. A good agreement are obtained between observed group velocities and theoretical ones. All of the group velocities for different periods and shear-wave velocities for different depth ranges are mapped to show velocity changes in the study area. The region having low group velocity values corresponds to a thin crust and higher ones corresponds to a thick crust. Average crustal thickness is about 40 km around the station TBZ and it increases from TBZ to the southeastern Turkey to about 43 km. Average crustal thickness is about 44 km in Lesser Caucasus and is about 43 km at the Turkey-Iran border region. At the Armenia-Turkey border region average crustal thickness is about 40 km. The values are in agreement with the earlier studies.

ANALYSIS OF INNER CORE S- AND P-WAVES

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The existence of a solid inner core was proposed by Inge Lehman in 1936, when she observed PKiKP waves which are reflected at the inner core boundary. Normal mode observations also support earth models with a solid inner core. So far, no body waves have been identified with a shear wave part in the inner core and therefore direct, observational evidence of solidity is still lacking.
The outer core being a liquid, phases should exist which travel as compressional waves in the outer core and as shear waves in the inner core, i.e. PKJKP, SKJKP etc. However, the amplitudes of these waves as predicted by PREM are small and the waves are probably not visible on single traces. Stacking methods in the slowness-time domain are therefore needed to improve the signal to noise ratio. Because of their small amplitude, these waves should only be visible in large earthquakes. Using a Phase Weighted Stacking method (Schimmel & Paulssen, 1997), we investigated data from the deep Bolivia earthquake of 9 June 1994 with a depth of 640 km. Real data stacks are compared with synthetic data stacks, computed with WKBJ ray tracing. Inner core P-waves, namely PKIKP and SKIKP, are easy to recognize and there is a good agreement between the real and synthetic data stacks. We analysed inner core S-waves in a similar way and present evidence of their existence.

RECEIVER FUNCTION ANALYSIS FOR THE STATION TBZ, TURKEY

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We use teleseismic three component digital data from the Trabzon, Turkey, broad-band seismic station to model crustal and upper-most mantle structure by receiver function method. The station is located at the transition from continental to oceanic formation. By inverting radial receiver functions, we construct one-dimensional crustal and upper-most mantle model that includes an anomalous shear-velocity inversion at about 25 km in depth. Arrivals on the tangential components indicate dip of crustal velocity discontinuities. This is consistent with gravity data that Bouguer anomalies drops sharply from Black Sea to Anatolia. The initial shear velocity assumptions for the upper crust are taken from Love wave solutions. No relevant moho Ps conversions are observed from receiver wave-forms even at high frequencies. In agreement with the theory that Black Sea region subducts under Anatolian plate, we qualitatively interpret the modeled velocity structure in terms of partial melting of subducting plate under Pontides volcanic mountain range. The low velocity zone extends down to about 75 km depth on the Anatolian side and relatively shallow towards Black Sea, and deeper the velocities increases sharply again. This velocity increase is interpreted as the remnant of the old subducting lithosphere. The strong misaligment of tangential wave-forms suggest anisotropy for the arrivals that converted at shallow depths including the low velocity zone. At this station just above the presumed subduction zone earthquake observations are made for the last two years and seemingly no observation is made relevant to it. Clearly, the subduction took place and is presently aseismic.

DIFFERENT APPROACHES IN THE LOCAL EARTHQUAKE TOMOGRAPHY: AN APPLICATION ON ALBAN HILLS VOLCANO (CENTRAL ITALY)

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We compare the results of tomographic inversions with two different approaches on the Alban Hills Volcano located at about 20 km southeast of Rome. In first approach, 3-D solution is obtained as progressively focusing toward to center of volcano, decreasing the model grid spacing in subsequent inversion and optimizing 1-B initial model ("graded inversion", Chiarabba at all. 1994). In the second approach, arrival times are inverted directly using 1-D optimal initial velocity model. Different denser grid spacings (2, 1.5, 1 km) in the 3-D models are used to obtain more detailed images of the volcano. A performing carefully resolution analysis on the model parameters permits which model is more reliable and which one gives the best result. Our principle result is that the inversion with graded approach can give unsatisfactory results without ensuring to detect some small scale inhomogeneties which can be retrieve from the data. The results of the inversions with the second approach reveal a horn shaped high velocity structure and dominant low velocity anomaly beneath the volcano at 1-4 km depths with more details.

ON THE ORIGIN OF SCS AND PCP PRECURSORS

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In 1983, Lay & Helmberger observed a small precursor to ScS, which they interpreted as a triplicated arrival caused by a discontinuity in the lowermost mantle. Alternative interpretations include small-scale scattering near the core-mantle boundary and near source slab effects, but most recent studies attribute precursors to core-reflections to a lowermost mantle discontinuity. Precursors to ScS and PcP have been observed in numerous locations, but are not a global phenomenon. Frequently, PcP precursors are weak or absent when ScS precursors are observed in the same location, and vice versa. The amplitude and arrival time of the precursor relative to the main phase can vary significantly. The presence or absence of these precursors has led to speculations about the nature of the lowermost mantle, culminating in a suggestion for the existence of 'anticontinents' at the core-mantle boundary. We propose that these precursors may be produced by gradients in seismic wave speed associated with large-scale mantle heterogeneity.

SHEAR WAVE PROPAGATION UNDER NORTHEAST ANATOLIA

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We use broad-band seismograms to model the shear wave propagation of higher modes of Lg type under Anatolian crust. The modelling suffers numerical instabilities at high frequencies. The computation time is very high. Computer programs written is so design to alleviate the numerical instabilities, and Filon's method is used to reduce the computional time. Reflectivity method which models both upgoing and downgoing waves is utilized. The seismicity of right lateral north and left lateral east Anatolian strike slip faults are usually shallow around 10-15 km. Small and moderate size earthquakes with high frequency shear wave propagations are observed. We use one dimensional velocity profiles formerly published in the literature and extend them as necessary due to the lateral hetorogenity. In the first 15 km depth range SH velocity gradient is high, rising from 2.7 to 3.6 km/sec. This depth range controls the Lg velocity of 3.4 km/sec and shows a group velocity stationary phase. Another velocity gradient lower than the first appears to start from about 25 km depth and below that moho shows a smooth transition of thickness about 5 km at around 35 km in depth. This velocity profile results the Lg propagation for focal depths as deep as moho, but the frequency content is reduced as the focal depth increases. It is sometimes possible to observe the source time complexity looking at Lg waves of several band-pass filtered forms.

CORRELATIONS BETWEEN SAR-ARC INTENSITY AND SOLAR AND GEOMAGNETIC ACTIVITY

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Statistical relationships between SAR-arc intensities and solar and geomagnetic indices are investigated using data acquired by the Pacific Northwest Laboratory Photometer network during the time interval 1978-1988. We have found that all SAR-arc events can be subdivided into two groups in accordance with characteristic properties of studied relationships. It is shown that electron temperature time variations with the characteristic heating time from minutes to several hours, which are observed in the SAR-arc regions, result from the time variations of the ring current parameters. We have found that the electron thermal conductivity dominates over the electron cooling rate at altitudes closely and above the maximum volume emission rate. As a result, there are no significant correlations between the SAR-arc electron temperature and density.

EFFECTS OF THE SUBDUCTING PACIFIC PLATE ON THE UPPER MANTLE SEISMIC DISCONTINUITIES

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We present images of the Earth's upper mantle obtained from P-S converted phases from teleseismic earthquakes which show upper mantle dicontinuities from the crust–mantle boundary to 660 km depth beneath the broadband seismic stations in northeast China and central Japan near the subduction zone. The main upper mantle discontinuities near 410 and 660 km depth (the '410' and '660') are clearly visible in the images underneath each station. They show however peculiarities: The '660' dips torward the west under northeast China, while near the Mongolian border the '660' is again at its global average position. This can be interpreted as an effect of the Pacific slab not penetrating but laying atop of the '660'. Additionally, we find no evidence for the existence of the '410' where the Pacific slab passes this depth under Japan and NE China. The locally absent '410' is consistent with extreme deformation (warping) of the discontinuity in a confined region at the subduction zone, caused by the dynamic transport of olivine into metastable conditions below 410 km depth.

SORET DIFFUSION EXPERIMENTS AND IMPLICATIONS FOR THE EVOLUTION OF EARTH'S CORE

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Soret diffusion rise times were observed and resolved for Fe-Ni-S-P melts at 10 kbar in thermal gradients between 1200-1450 C. A steady state separation of S-rich components to the hot end of the 2 mm long liquid charges is achieved in about 20 minutes. Chemical diffusivities of about 10^{-5} cm^2/sec are consistent with these observations and those of the compaction velocity of aggregates of crystalline Fe metal against the cold end of our experiments. These rapid diffusivities are not rapid enough for diffusion to be an important agent of bulk mass transfer in the addition or extraction of light elements in the Earth's core. Some implications of these observations in a thermodynamic model of the evolution of the core-mantle boundary are investigated. The core-mantle boundary is treated as a singular surface and a surface of solution. The liquid outer core is modelled as a solution layer. Some aspects of mass transport to the inner core boundary are considered. Local equations for the diffusion-controlled and interface-reaction-controlled rates of mass transfer across the core-mantle boundary are derived.

SE3

CONSTRAINTS ON UPPER MANTLE DISCONTINUITIES BENEATH THE MEDITERRANEAN REGION FROM P-TO-S CONVERSIONS

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P-to-S conversions from the two primary discontinuities of the upper mantle near 410 km and 670 km depths are detectable by deconvolution of teleseismic body waves recorded by broadband seismic stations. The preliminary results obtained by using data recorded at the MedNet stations, show variations of the depth of these discontinuities under the Mediterranean Region. These evidences could be explained as thermal anomalies correlated with the tectonic activity. A particular attention is dedicated to the subduction zones in which the anticorrelation of the two discontinuities is expected for a phase change origin for both discontinuities with Clapeyron slopes of opposite signs.

INNER CORE ROTATION : POSSIBLE ARTEFACTS AND NEW DATA

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A 1°-3° per year westward rotation of the inner core with respect to the mantle has been detected from the variations in time of the inner core anisotropy symmetry axis (Song & Richards, 1996 ; Su et al., 1996). These first detections rely on the assumption that the inner core anisotropy axis is tilted with respect to the Earth rotation axis. Whe show from the analysis of seismic data that the tilt of this axis is not a robust feature : the inner core anisotropy data are fully compatible with a symmetry axis parallel to the Earth rotation axis. Moreover, artefacts may arise from the use of analysis methods based on cross-correlation of core phases with different frequency contents.
Estimates of inner core rotation from the displacement of inner core lateral heterogeneities lead to significantly lower rotation rates (0.05-0.3°/yr, Creager, 1997) but the perturbing effects of mantle heterogeneities at source side (South Sandwich subduction zone) and station side (Alaska) are difficult to estimate. This difficulty may be avoided by the use of artificial sources. The variations with time of core phases travel time residuals are presented for the path Novaya Zemlya to DRV, Antarctica. This path corresponds to a small angle (14°) of the inner core ray path with respect to Earth rotation axis.

SE4 Hot spots and plumes in the mantle

Convener: Hansen, U.

RECEIVER FUNCTION CONSTRAINTS ON SLAB GEOMETRY AND UPPER MANTLE DISCONTINUITIES UNDER NORTHERN CHILE

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Source equalized receiver functions are routinely used to determine crustal velocities and upper mantle discontinuities. Here we present clear observations of the subducted Nazca plate from data recorded at two temporary station networks in northern Chile. The PISCO network was operating in 1994 with station spacing of about 30 km, located from the Pre- to the Western Cordillera. The CINCA network was operating in 1995 with closer station spacing in the Coastal Cordillera. Two deep Argentinian earthquakes recorded at PISCO show coherent phases of Ps conversions from the oceanic Moho of the eastward dipping Nazca plate. The receiver functions of three earthquakes from the South Pacific Ocean and Mexico are dominated by the multiples of PpPs which travel as P to the surface and are reflected off at the slab as S wave. Receiver function modelling indicates that the oceanic Moho is 40 km deep at the coast and dips 15 deg eastward under CINCA and increases its dip to 25 deg under PISCO. Our result is consistent with seismic refraction data (Wigger 1994). We have also seen the Ps conversion from the upper mantle discontinuities. The delay times of the 410km and 660km discontinuities suggest that the 410 is at its global depth and the 660 is depressed by about 10 km.

SEISMICITY OF THE NORTHEN PART OF THE EAST EUROPEAN PLATFORM AND ITS ORIGIN.

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The area to be studied the Fennoscandian Shield and North part of Russian platform is integrated. The shield is characterized by high level of seimicity. The magnitudes of earthquakes for the most part extend from 3 to 5. in some instances the magnitudes range up to 6. Occurence dept of eartquakes saurces is not more than 10-15 km. The epicenters of earthquakes form the belts extending in NE and NW directions. These directions conform with strike of foults dividing Fennoscandian Shield and Russian platform into separate tectonic blocks. Because of this the Earth crust of Fennoscandian Shield and Russian platform is charaterized by sharp unhomogeneity. Unhomogeneities stand out on gravity. magnetic. P-waves fields. Upper part of Earth crust is most unhomogeneous. The velocity of the vertical present-day movements is - 2.5 + 10 mm/year as in orogenic belts. There are several factors defining the present-day vertical moving and seismicity of studied area. The main of them are compessional stress field from the Artic middle oceanic ridge and unhomogeneities of upper mantle. Seismoactive faults of Fennoscandia extend to Russian platform. It is very impotant to determine their positions because nuclear waste stories and oilpipes are situated here.

ICELAND'S HOT NARROW PLUME

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We present the results of a seismological investigation of the frequency dependent amplitude variations across Iceland using data from the HOTSPOT (PASSCAL) array currently deployed there.
We use the parameter t^* to compare the variations observed with those predicted due to both anelastic attenuation and diffraction effects. t^* is obtained from teleseismic events at a range of azimuths using a spectral ratio technique. We use a 2D cylindrical plume model with a velocity anomaly from iasp91 based on a Gaussian curve. t^* due to attenuation is obtained by tracing a ray through iaspi91 with the plume model superimposed and calculating the path integral of $1/vQ$. t^* due to diffraction is obtained using a 2D finite difference code to generate synthetic seismograms, the same spectral ratio technique is then used to extract t^*
The best fit plume model has a maximum S-velocity anomaly of -12% and a Gaussian shape with $\sigma = 100$ km. This is narrower than previous estimates and would suggest greater ray-theoretical travel-time delays than observed. However we find that for such a plume wavefront healing causes a 40% reduction in the travel-time delay, reducing the ray-theoretical delay to that observed.

HOT SPOTS ON THE RUSSIAN CRATON AND EXOGENETIC MANIFESTATION OF THE VOLGA-KAMA'S PLUME

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Study of plumes and hot spots are especially difficult at the ancient power plates such as the Russian craton screening plume effects. Exogenetic manifestation of the Volga-Kama plumes such as the pluto-like bodies, as specific fluctuations of thermal, gravitational fields, as the Moho uplifts and as topographic features are investigated. On the Russian plate the hot spot is manifested in the form of arched lineament chain. The hot spot on the Russian craton may be related to the "warm" spot because its gradient temperature and heat flow are less intensive than at the thin ocean crust. Mantle convection has come under intense by geoscience since the new global tectonics including continents drift, plate tectonics in upper mantle, plume tectonics in lower mantle and growth tectonics in core. Dissipative effects arising from the core-mantle interaction are of particular interest a) as the source of additional heating of the Earth's interior, b) as the mechanism supporting free core nutation and c) as the region of plume arising. The model of vortex plume penetrating lower and upper mantle is discussed. The vortex plume is more stable under influence of different motions in the mantle. Such plume pins to the Earth's crust, discretely moves under crust conserving mushroom-like pluto-bodies in crust. The kinematic scheme of Russian plate motion in the Volga-Kama hot spot reference system is given.

STRESS FIELD, VISCOSITY AND SHEAR HEATING DISTRIBUTION IN MANTLE UPWELLINGS: A COMPARISON BETWEEN NEWTONIAN AND NON-NEWTONIAN RHEOLOGIES

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The attempt to measure mantle flows with seismic anisotropy has reawakened interest in the stress distribution of mantle flows. Stress fields which are concentrated in boundary layers would be accompanied with shear heating, that would be amplified by both the strain-rate and temperature dependent nature of mantle rheology. For resolving the thermal-mechanical fields accurately, extremely high resolution, O(km), is required. We have modeled strongly time-dependent two-dimensional upper-mantle convection with a resolution of 2 km in an aspect-ratio four configuration. We have focussed our attention on the upwellings at an effective Rayleigh number close to 2×10^6. There is a marked difference between the non-Newtonian and Newtonian rheologies. The magnitudes of the stress and viscosity fields are much lower for the non-Newtonian rheology. The rate of viscous heating is much greater for the non-Newtonian rheology, as well as the peak vertical velocities, which surpasses the Newtonian upwelling speeds by more than an order of magnitude. Stress distributions are much broader for Newtonian upwelling and display more greater spatial complexity for non-Newtonian flows. Our results would suggest that seismic anisotropy developed by non-Newtonian plumes in the upper-mantle would be difficult to be detected, because of the much finer spatial scale.

SE5 Geodynamics of the lithosphere: images and models of active tectonics

Convener: Furlong, K.P.
Co-Convener: Wortel, M.J.R.

GLOBAL HEAT FLOW AND THE FREQUENCY-SIZE DISTRIBUTION OF PLUME STRENGTHS

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Hot spot volcanism and the associated lithospheric swells are generally attributed to mantle plumes. The amplitudes of the swells have been used to quantify the buoyancy and heat fluxes associated with these plumes. We hypothesize that plume frequency-size statistics are power-law (fractal). We find good agreement with the largest plumes, $N_C = 1.33B^{-1.35}$, where N_C is the total number of plumes with buoyancy flux $\geq B$. *Sclater et al.* (1980) have estimated that 60% of the total GHF (global heat flux) is due to plate tectonics; a fundamental question is whether the remaining 40% can be attributed to plumes or another form of secondary convection. *Sleep* (1990) and *Davies* (1988) estimatee that about 6% of the total GHF is due to plumes. We extrapolate the power-law relation, $N_C = 1.33B^{-1.35}$, to smaller plumes and find that if 40% of the total GHF were due to plumes, 10,000 plumes ranging from $0.01 < B < 9$ Mg/s (Hawaii) would be needed. A significant heat flux is associated with these smaller plumes, many of which do not leave a surface expression. Although there is no direct evidence for these plumes, the flattening of the oceanic lithosphere subsidence at 100 Ma, and the heat input to the base of the continents, provides indirect evidence for their existence.

EVIDENCE FOR HOTSPOT MOTION FROM THE EASTER TRACK / NAZCA PLATE

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Reconstructions of absolute plate motion in the Pacific region are based on the assumed fixity of the Hawaiian and Louisville hotspot. Dynamical models of plumes moving in large-scale mantle flow however can produce an equally good fit to both observed tracks but yield a different absolute plate motion. Since our models predict a westward motion of the Easter plume relative to Hawaii and Louisville of up to several cm/year, the Easter hotspot track can be used to test the case of hotspot fixity. Here we present self-consistent reconstructions of Pacific and Nazca plate motion and evolution of the plate boundary in closely spaced time intervals, considering both ridge migration and ridge jumps. We show that for a sufficiently strong westward motion of the Easter hotspot, which some of our models show, the hotspot does in fact leave a track on the Nazca plate with a predicted age progression that matches age data. The predicted track however tends to be further to the south than the observed ridges. We use different scenarios that lie within the considerable uncertainties of both plate reconstructions and predicted hotspot motion to optimize the fit of both topographic trends and age data along Nazca and Sala y Gomez ridges and can thus give some additional constraints on spreading history. Particularly, it is tested, whether the fit can be improved if a rather recent change to the current spreading direction is assumed.

GEODYNAMIC EVOLUTION AND NEOTECTONICS OF THE BLACK SEA REGION

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An analysis of the Phanerozoic evolution of the Black see region shows that at least from Paleozoic regior evolved as an active margin of the Northern Tethys comprising oceanic and continental arc-back arc systems. The whole region seems to represent a West Pacific type long living accretionary assemblage. Geologicaly the region represent a mosaic of microplates and blocks (Turkish, Armenian, Transcaucasian, Grater Caucasian, Black Sea, South Caspian) separated from one another by large fractures in the^hs crust faults, thrusts, strike-slips. These boundary zones represent belts of maximum geodynamic activity - tectogenesis, volcanism, orogeny. Simultaneously, they are also the main seismoactive zones of the region. The largest of these zones-the North Anatohan fault extends for about 1500 km from the Marmara sea to Iran. The main seismoactive zones in Armenia - the Sevan-Akera and Erevan faults represent NE branches of the NAF. Another large seismoactive structure of Eastern Anatolia, the East Anatolian fault, has ir^robable extension in Georgia in the form of the Abul-Samsar seismoactive fault.

SE4 SE5

3D MODEL OF THE CRUSTAL STRUCTURE IN EASTERN ROMANIA

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The main tectonic feature in Romania - Carpathian Orogen - is bounded on the North and North-East by the East European Platform and on the East and South by the Moesian Platform. Inside the Carpathian Arc are the Transylvanian and Pannonian intra-arc basins.
Three main types of crustal structure have been identified in Romania:
1.Geosynclinal type (40 - 50 km thick) in Eastern and Southern Carpathians;
2. Platform type (30 - 40 km thick) in Moesian and Moldavian Platform;
3. Depression type (26 - 33 km thick) in Pannonian and Transylvanian Depression.
Between these main types is situated the subcontinental model of the Black Sea crust with thickness of 25 km. Exceptions from the above classification are : 1. The crust of the Apuseni Mountains, which is considerable thinner than in Eastern and Southern Carpathians, and the crust which correspond to the molassic Neogene Foredeep situated in front of the Carpathian South Eastern salient (43 - 45 km). All the information available about the lithosphere structure has been gathered from the results of the refraction and reflection seismic lines as well as from punctual seismic recordings. They were integrated in the 3D images of the Moho discontinuity and the base of the lithosphere for Eastern Romania.

DYNAMIC REGULARITIES OF THE PLATE MOTION

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These regularities were established as results of analysis of the plate dynamic characteristics (vectors of momentum and angular momentum, their components and oth.). Mentioned characteristics were defined for model of the plates (Barkin, 1995) moving in accordance with kinematical theory HS2-NOVEL1 (Argus, Gordon, 1991) and oth. 1. Poles of momentum and angular momentum vectors of the plates are situated around three orthogonal great circles. 2. Vectors of momentum and of angular-momentum of the each plate are orthogonal; 3. Relation of the modules of angular momentum of two arbitrary plates are equal by relations of theirs modules of momentum; 4. Modules of angular momentum of the plates are rationally-commensurebility and are defined by relation $G_n = 2^n G_0$, where G_0 is universal value of angular momentum, and n is integer. Obtained empirical relations and regularities 3. and 4. by its form are similar by Keplerian law and Tizius-Bode law for a system of the celestial bodies.

THERMAL-KINEMATIC MODEL OF A SUBDUCTING SLAB

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We present results from two-dimensional numerical experiments on the thermal and kinematic evolution of the subducting slab and the overlying mantle wedge for a range of subduction parameters. They include subduction rate and dip angle. One goal is to determinate how different parameters control the thermal evolution of the slab-wedge interface, from subduction initiation up through roughly 400 km of subduction. An addictional goal is to define optimal conditions for the melting of slab sediments and crust. Maximum wedge temperatures are recorded at higher subduction rates and are found to be strongly dependent on factors influencing return flow into the wedge, such as the reology of the litosphere (rigid or ductil). The dehydration history of the subducted slab and the location of mantle wedge melting have been inferred after a comparison between computed P-T-t paths and phase diagrams for hydrous basalts and ultramafics. The effects of both fisical and numerical parameters on thermodynamic modeling of subduction zone environments have been evaluated.

MODULATED THERMOCONVECTIVE WAVES IN THE CONTINENTAL LITHOSPHERE

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For flows associated with small strains, rheology of rocks is described by the linear integral (having a memory) law which reduces to the Andrade law in the case of constant stress. The continental lithosphere with such a rheology is overstable. Thermoconvective waves which can propagate through the lithosphere without attenuation have a period of about 200 Ma and a wavelength of the order of 400 km. Various initial temperature perturbations in the lithosphere leads to different wave patterns: packets of waves or standing waves with amplitude modulation. Thermoconvective waves induce oscillations of the Earth' surface accompanied by sedimentation and erosion and can be considered as a mechanism for the set of sedimentary basins and interbasinal arches on the cratons.

TRANSFORM-SUBDUCTION TRANSITIONS: A COMPARISON AT BOTH ENDS OF THE ALPINE FAULT, NEW ZEALAND

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Marine geophysical data collected over the Fiordland and Hikurangi margins at the southern and northern ends of the strike-slip Alpine Fault (AF), together with other data show that the AF-Puysegur subduction transition differs from that of the AF-Hikurangi subduction. At the Fiordland margin, the transform-subduction transition is sharp and accommodated by a tear fault in the downgoing plate. The tear propagates seaward along the Resolution Ridge Fault System, a major crustal discontinuity in the downgoing plate, which lines up with the AF and controls its development. At the southern Hikurangi margin, the transform-subduction transition is progressive and occurs by the way of motion partitioning between the subduction interface and upper-plate strike-slip faults. Motion partitioning results from an inter-plate coupling that increases toward the AF in relation with a progressive thickening of the down-going plate. The thickening represents a crustal discontinuity between the oceanic Hikurangi Plateau and the northern edge of the continental Chatham Rise that trends obliquely to the AF. The comparison between these 2 transform-subduction transitions shows that the presence of an inherited crustal discontinuity in the down-going plate, its type, and orientation with respect to the plate motion are factors controlling the structural style of the transition.

MODEL FOR INELASTIC POSTSEISMIC DEFORMATION

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With the advent of modern, precise, space-based geodetic observational techniques, particularly including continuously recording GPS stations and Interferometric Synthetic Aperature Radar systems, has come the need to interpret these data using the best available models for earthquake-induced deformations. Because the data observed to date following major earthquakes clearly shows the presence of inelastic processes operating in the earth's crust, appropriate models must include the effects of inelastic stress relaxation, near the fault and at depth in the crust. At the same time, new advances in both computational performance and availability are stimulating the development of new methods for simulating the dynamics of the earthquake cycle. These simulations demand the use of the best available technology for calculating stress relaxation and redistribution, using Green's functions for the processes. In this talk, we present the models developed by our group and indicate how and where they may be obtained for general use by others (e.g., anonymous ftp: /fractal/users/ftp/pub/Viscocodes at fractal.colorado.edu).

NUMERICAL MODELLING OF BASIN EVOLUTION IN THE NORWEGIAN-DANISH BASIN

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Tectonic subsidence curves in the Norwegian-Danish Basin show that the main rifting phase took place in Upper Permian and Triassic. This event is the subject of this paper. Observations of crustal thicknesses, and analysis of the subsidence history, support that lithospheric extension is a major ingredient of the basin forming process.
Structural and stratigraphic data for the modelling are extracted from a 400 km profile across the basin. The sedimentary thicknesses along the profile are taken from isopach maps.
The thermo-mechanical behaviour of the lithosphere is simulated by an elasto-visco-plastic rheology in a plane-strain finite element model. Sedimentation, erosion and compaction of sediments are included in the thermal model. Eustatic sea level changes and paleo water depths are taken into account. A simple start model is used consisting of pre-rift sediments, crust (wet quartz) and mantle (wet olivine) material. A heat flow anomaly is used to weaken the lithosphere prior to rifting.
The infilling of the basin till end Cretaceous can be explained by extension in Upper Permian and Triassic, variations in eustatic sea level and paleo water depth, and sediment compaction.

MANTLE DRIVEN ACTIVE TECTONICS AT THE MENDOCINO TRIPLE JUNCTION, CALIFORNIA

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At the Mendocino Triple Junction (MTJ), the western margin of the North American plate changes from convergent north of the triple junction (Cascadia subduction zone) to translational south of the triple junction (San Andreas transform). Plate kinematics in this region would imply that most crustal shortening should occur north of the MTJ associated with plate convergence. However the process of crustal shortening does not follow this pattern; rather a discrete region of crustal thickening (shortening) forms in association with the slab window produced at the triple junction. With passage of the MTJ, a slab window forms immediately south of the triple junction. The influx of asthenospheric mantle into the slab window produces both thermal and mechanical modifications to the plate boundary regime. In particular, the upwelled material cools and accretes in a complex fashion to the Pacific, North American, or Juan de Fuca plates bounding the triple junction. This complex pattern of accretion leads to relative plate motions from north of the MTJ (Juan de Fuca - North America) being applied south of the MTJ to the base of North America - resulting in a localized region of crustal shortening and thickening of the North American crust. This mechanical crustal thickening is then further modified by magmatic additions derived from the emplaced asthenospheric mantle.

LITHOSPHERIC TECTONICS OF A TRANSPRESSIONAL PLATE BOUNDARY: FIORDLAND, NEW ZEALAND

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Transpressional plate boundaries are locations of complex crustal deformation. Although these boundaries often show evidence of strain partitioning in the crust, how strain is accommodated on a lithospheric scale is unclear. Fiordland, in the SW corner of the South Island of New Zealand provides an excellent locale to study the evolution of a transpressional boundary. It sits at the northern end of the Macquarie Ridge - Puysegur plate boundary between the Pacific and Australian plates. The region was purely translational during the Miocene (20 Ma-5 Ma), with a change to more transpressional kinematics during the past 5 Ma. The combination of deep seismicity, a significant Bouguer gravity high, and exposed middle crustal rocks in Fiordland indicate that support for the elevated topography comes from processes associated with transpression. This tectonic style is a consequence of the plate boundary geometries at the initiation of transpression - in the Fiordland region the 3-D geometry during the translational phase included a lateral offset between the near surface and deeper plate boundaries. This initial condition allowed the lithosphere in the region to accommodate transpression without concomitant thickening in the superjacent crust, as has occurred further north in the NZ Southern Alps.

INITIATION OF INTRA-PLATE SUBDUCTION DUE TO END-PLATE COMPRESSION: NUMERICAL APPROACH

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It is recognized that end-plate compressional stresses may induce folding of oceanic and continental lithosphere. If these forces remain constant long enough through time, folding of the whole lithosphere develop and simultaneously faulting within competent layers. For continental lithosphere with a relatively stong non-uniform stratified rheologies, shear zones appear at the inflexion of the folds, go through the lower crust and connect deformation in the upper crust and into the upper mantle. Deformation may localize in several shear zones that go through the whole lithospheric thickness: a new subduction zone can initiate. Depending on rheologies and softening properties of brittle behaviour, we show different scenarios of accomodation of deformation. There may not be one subducting plane at the beginning, because gravity forces work against further underplating. Therefore major shear zones jump around a few times, while the whole lithospheric material is on the verge of failure and undergoes softening. Finally, one major shear zone may win and accomodate the whole deformation by subduction. Study of rheologies, topographic evolution, taking into account erosion and sedimentation, help to constraint which places in the world are susceptible to be a further intra-plate subduction zone.

EVOLVING TECTONIC STRUCTURES IN ROMANIA

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Vorotilov drill hole stress measurement stated that East European Plate has its own stress direction N 137 degree E, wich are in good agreement with those measured for Central Europe, of N 145 degree E (counter clockwise rotation ?)(K.Huberm, Tectonoph.,1997). Paleomagnetic measurement made in Apuseni Mountains (Romania) stated that this area not only that it suffered a clocwise rotation, but it is not on its birth site, being brought here from lower altitudes, and those combined movements started in Laramian orogenesis(Patrascu, 1988). Albania paleomagnetic meaurementes stated that clockwise rotation was a general movement for Albanides, Circum-Rhodope and the Serbo-Macedonnean massif (Mauritsch,Tectonoph.,1995). Geophysical data in Apuseni Mountains suggest that Carpathian Alpine Chain is disposed onto an old suture zone, wich originally was a rifting zone, ophiolites being found outcropping, and then migrated eastward. Alpine plate Eastward pushing, made what is now Carpathian encourbed belt, the hanging wall being EEP. Vrancea earthquake area is just an remnant from those huge plates struggle.

NUMERICAL SIMULATIONS OF TRANSPRESSION

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In various present-day regions, transpression is responsible for thickening and uplift of the crust (e.g. Puysegur Trench-Alpine Fault, South island, New Zealand; San Andreas Fault, Southern California). In most cases, it is not clear on the basis of available data whether convergence along the strike slip fault has evolved into steady state subduction of oceanic lithosphere with a significant strike slip component. The evolution from pure strike slip to mature oceanic subduction (if it ever occurs) is investigated following a change in relative motion from strike slip to transpression. Numerical simulations of the (thermo-)mechanical evolution of an ocean-continent plate boundary are used. Aims are 1) to identify in the numerical results observables that can be used to infer the stage of convergence in these regions, e.g. patterns of strain, horizontal and vertical motion, metamorphic grade and sediment distributions, 2) to determine the amount of normal convergence necessary to arrive at steady state subduction, and eventually, 3) to be able to better understand orogens that were formed in transpressional settings in the past, like the Alps or the Betic Cordillera. First results are presented of simulations for well established ocean-continent transform faults that are subjected to moderate amounts of convergence. Rheological contrasts and relative buoyancy play a fundamental role in the behavior of the system. Laboratory-derived rock mechanical properties and realistic geotherms are used to constrain possible rheological contrasts.

CHARACTERIZATION AND MODELING OF THE INTRAPLATE DEFORMATION IN THE WHARTON BASIN (N-E INDIAN OCEAN)

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The Indian Ocean east of the 90°E Ridge is underlined by an intense and presently active intraplate deformation. Multibeam bathymetry and seismic data gathered during the *Samudra* cruise (N/O L'Atalante, 1995) reveal three active N5°E left lateral strike-slip faults at least 700 km long. These faults reactivate fossil transform zones associated with the presently extinct E-W spreading centre of the Wharton Basin. Focal mechanisms of the global seismological network are in agreement with left lateral strike-slip, and suggest that the intraplate deformation may affect a large part of the Wharton Basin: the whole basin could be cut in long N-S slivers. The style of deformation contrasts with the one documented for the Central Indian Ocean, west of the 90°E Ridge, where pure N-S compression occurs and reactivates ancient normal faults inherited from seafloor spreading. The difference may be explained by the nature of the northern plate boundary: a colli! ! sion boundary north of the Centr al Indian Ocean and an oblique subduction boundary north of the Wharton Basin.

In this study we present a numerical model accounting for the observed deformation pattern. We discuss the influence of the boundary conditions, especially the northern ones, and the role of preexisting weakness zones in the oceanic lithosphere of the Wharton Basin.

MATHEMATICAL MODELLINING OF THE MOVEMENT OF A LAYER MELTING IN THE EARTH.

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When bulding the mathematical model both the melting process of Earth and forming its crust it is necessary to treat as minimum bi-component earth containing fusible and refractory fractions. Moreover, the fusible fraction contains more radioactive sources of heat. The mathematical model has to reflect two processes: the heating process which results in melting, and a process of redistribution of components by convecting. In this paper we offer a model of solving the problem of heat conductivity and defining the melting zone, i.e. Stephan's problem. Since separating the components depends on convection and not on diffusion therefore it is done more rapidly than the movement of the melting layer, so we consider that the process of redistribution of the components takes place practically in an instant. That's why we describe that process in the equation of the balance of the substance thinking that the refractory fraction crystallises first and then fusible fraction while the melting layer moves. The algorithm in this paper allows for solving Stephan's problem at a variable critical temperature at the presence of numerous layers of melting.

ELEMENTS OF ELASTIC SYMMETRY OF THE 3rd AND 5th ORDER IN CORE SAMPLES FROM THE KOLA SUPERDEEP BOREHOLE IN THE DEPTH INTERVAL 9- 12 KM.

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Spatial position of elastic symmetry elements of the core samples from the Kola Superdeep Borehole in the range from 9 to 12 km have been investigated by means of acoustopolariscopic method. Stress field existing on the moment of rock formation determines elastic symmetry of rocks. Commonly, a stress field is determined by three resultants of all acting forces, that suggests two components in each plane normal to the resultants and element of elastic symmetry of the second order. Some of our samples reveal elements of elastic symmetry of the 3rd and 5th order and a lot of them reveal transitional types of symmetry. That is illustrated by acoustopolariscopic shapes, where modification of 2-4-petal form to 3-5-petal takes place. This effect is a result of modern reconstruction of stress field structure in the deep interval. Superposition of new elements of elastic symmetry on rocks with paleostresses gives an opportunity to observe the presence of old as well as new elements of elastic symmetry simultaneously. The lack of equilibrium in stress state of rock-massifs leads to the decreasing of rock strength.

ACTIVE DEFORMATION OF EASTERN INDONESIA AND THE PHILIPPINES INFERRED FROM SEISMICITY AND GEODETIC DATA

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The eastern part of Indonesia and the Philippine region is an area of complex deformation where plate boundaries are being reorganized in response to the arrival of Australian continental material at the Banda trench. We investigate the nature of deformation in this region through an inversion of shallow focal mechanisms from the Harvard CMT catalog and GPS data (Genrich et al., 1996; Puntodewo et al., 1994) for a regional strain rate and velocity field.

A strain rate field derived from seismicity alone is strongly dominated by the largest 5 events in the catalog and velocities are only about 10% of NUVEL-1a. Inherently such a picture only illustrates short-term deformation as the length of the CMT catalog is significantly less than estimated recurrence times for these large events. We find however that the seismic strain field is moderately self-similar for events with moments less than 1e20 Nm. The smaller events were used in a joint inversion with available GPS data, where the seismicity is only used to characterize the style of deformation. This results a strain field that clearly illustrates the effects of strain partitioning in northern Irian Jaya and the Philippines, as well as the change from convergence along the trench west of Sumba to convergence in the back arc region east of Sumba.

THE GLOBAL DISTRIBUTION OF AVERAGE (5 x 5 DEG.) DEPTHS OF MOHO DISCONTINUITY: IMPLICATION TO PLATE TECTONICS

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The all available seismic data for the thickness of the earth crust were compiled and averaged in the 5 x 5 deg. grid for the whole earth. For any distant and inaccessible, poor known regions, like high mountains of the Middle, South and Little Asia, American Cordilleras and Andes, Antarctica, Greenland and so on, these data are absent. For such regions the depths of Moho discontinuity (M) was estimated by means of the correlations between the crust thickness, topography and Bouguer gravity anomalies. The resulting map of M depths is drawing. It is seen, that average M depths are different for the various lithospheric plates. The greatest values are on the European plate (maximum is 63 km). The Northamerican, Southamerican and Australian plates show the depths to 50 km, on African and Antarctic plates maximum is 40-50 km.The average M depths on Pacific plate are greater (to 15-20 km), than on Cocos and Nazca plates (9-10 km). In Atlantic ocean we see the average M depths to 10-13 km on the North and to 17 km on the South Atlantic. The Indian plate has the M depths 10-19 km. The lower values are on the vicinities of mid-ocean ridges. The regions of East Pacific Rise, Mid-Atlantic Ridge and Ninetyeast Ridge are traced by average M depths 10-11 km. On the Southwest and Southeast Indian Ridges these values are rather greater (to 13-14 km).These differences are connected apparently with the ages of lithospheric plates. These data allow to estimate the gravity contribution of the earth crust to the whole gravity field of the Earth. This work has been supported by Russian FundamentalResearch Foundation No. 97-05-64342.

Rock Masses Transposition and Genesis of Variscan Plutonites in the Bohemian Massif

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Plutonites belong to the dominanting rocks of the Bohemian Massif. Their genesis seems to be associated with the transposition of rock material in the Variscan plate rotation. Plutonites are concentrated into large bodies / the Central Bohemian Pluton, the Moldanubian Pluton.../the shape of which, according to geophysical methods, have been assumed to be conoidical. For Variscan plutonism, the older prevariscan construction was significant. The prevariscan blocks preserved their "roots" in a lower crust, the upper solid parts are rotated and pressed to the depth. Under pressure conditions from 3 to 5 kbar and temperatures 600 -700^C, the melting process of prevariscan rocks gives the genesis of granitoid. As the assumed azimut of the force vector which is responsible for rotation tends from NW, the blocks located more to the West are pressed prior to those located more to the East. The course of the blocks deformation is not continuos, the simple rotation is complicated by the contact with another plate on the East. We can recognize two fases of this motion , as the orginal compressed zones are changed to extension. In this process the place for plutones implantation is made. This doublefases process is confirmed by two groups of rocks of different, however Variscan, age.

RECENT SUPERINTENSIVE DEFORMATIONS OF PLATFORM FAULT ZONES

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Superintensive deformations (SD) of the surface with a speed of up to 70 mm per year have been discovered lately in the zones of "stable" platform faults traditionally considered as calm (with a low activity of deformation process 1 mm per year). It radically alters the established notion about the platform areas as regions "with a low activity of crust movements". Up to this time these traditional notions have made it possible to design and employ openly ecologically dangerous objects (nuclear and hydroelectric power stations, deposits of oil and gas et al.) without consideration and knowledge of possible negative consequences of SD-processes in platform fault zones. The described new approaches are based on a bank of unique information have been collected for many years on the geodynamic and technogenic polygons of the FSU. The method of assessment (including geodetic data and modeling of crustal deformations) and forecast of ecology-geodynamic risk was developed from this results for this time in the world.

TECTONICS AT A TRANSFORM-SUBDUCTION RELAY ZONE, THE PUYSEGUR AREA, SOUTH OF NEW ZEALAND.

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South of New Zealand, the PAC-AUS plate boundary comprises the Puysegur oblique subduction that becomes incipient southward, where it is left laterally relayed by the Puysegur dextral strike-slip fault. Geophysical data indicate that the relay zone consists of a series of transpressive faults splaying northward in a fan shape fashion from the Puysegur Fault toward the trench. A braided pattern of oblong and sigmoid ridges and basins is characteristic of the surface expression of the transpressive faults. Because no other major active deformation zone is found either north or south of the relay we inferred that the relay transfers most of the plate motion from the Puysegur Fault to the subduction front. The connection between the transpressive faults and the Puysegur Fault occurs in N-S trending basins that may have resulted from transtension. The basins bound the NE termination of an oceanic terrane that appears to be translated northward between the Puysegur Fault and the trench. We believe that extension resulted from the trenchward collapse of the terrane following the subduction initiation. Subsequent transpressive motion has started to shorten the basins. The development of the relay, which appears to migrate southward from the continental landmass of New Zealand to the oceanic domain, accompanies the development of the subduction.

SURFACE WAVE DIFFRACTION TOMOGRAPHY OF THE SOUTHEAST ASIA MARGINAL BASINS

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We model full long-period seismograms including the contributions from scattered waves. A two-step procedure is followed for every record. First, we compute synthetics using the WKBJ approximation and apply non-linear optimization to find an average model along the source-station path that minimizes the data-synthetic misfit. Secondly, we use the Born approximation to model the propagation of the surface wave modes more realistically. The sensitivity of the waveform to structural perturbations in the area of the path is computed. In this way, we can relate the misfit of the WKBJ synthetics to 3-D heterogeneity around the path. This results generally in 15-40 linear constraints (equations) for the S velocity anomaly in the vicinity of each path. We compute a 3-D tomographic model in a linear inversion combining the equations from many paths, and compare this with the model obtained using only the WKBJ approach.
We apply the method to image the upper mantle velocity structure in the Western Pacific - Southeast Asia region. Preliminary models constrained by a few hundred seismograms will be presented.

EVOLUTION OF THE PAC/AUS PLATE BOUNDARY SOUTH OF NEW-ZEALAND: INITIATION OF THE PUYSEGUR SUBDUCTION ALONG A STRIKE-SLIP PLATE BOUNDARY.

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Marine geophysical data collected during the GEODYNZ cruise along the PAC-AUS plate boundary, at the transition between the intra-continental Alpine Fault (AF), the Puysegur subduction and oceanic Puysegur Fault (PF), together with a kinematic reconstruction of the plate boundary provide new insights about subduction initiation along a strike-slip plate boundary. These data show that prior to the AF formation, about 25 Ma, the Puysegur Fault and intra-continental Moonlight Fault formed the strike-slip plate boundary, that was connected to a spreading centre in the S-E Tasman Basin. After the onset of the AF, an intra-continental transpressive relay formed between the AF and the PF. Strike-slip motion led, 20Ma, to the juxtaposition of oceanic and continental crusts along the transpressive relay, suggesting that oceanic subduction initiated at that time. About 5Ma, an increase of the plate convergence favoured the propagation of the subduction along a pre-existing fracture zone adjacent to the PF. The Puysegur example suggests that subduction initiation along a strike-slip plate boundary requires: 1- a transpressive relay to localise the compressive deformation; 2- juxtaposition of crusts with different thicknesses and densities; 3- an increase of the plate convergence vector; and 4- inherited structures to facilitate the subduction development and propagation.

MODELLING OF THE FIRST ORDER DYNAMICS OF THE EURASIAN PLATE; APPLICATION TO THE ALPINE THRUST

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A set of models is presented for the first order dynamics of Eurasia. The research essentially falls into two parts. The first is the description of a plate geometry, with plate tectonic forces applied to it, which are constrained using realistic physical assumptions. As a result, two families of force models are identified, which show similarities, such as a comparable upper limit on transform fault resistance, and differences, such as the nature of basal drag. The second part is the subsequent stress modelling using selected force loads for the plate, and interpreting the results in terms of plate scale stress patterns. The models using small resistive basal drags and moderate boundary forces provide the best explanation of stress observations compiled in the World Stress Map (WSM) data base. The modelled stress field is characterized by generally compressive tectonic stresses in the range of $20-40MPa$, with S_{Hmax} orientations coinciding well with the large-scale patterns identified in the WSM. The latter include the stress provinces of Western Europe, which is controlled by ridge push and Mediterranean collision processes, and Eastern Asia, caused by the indention of the Indian Plate into Eurasia. Investigation of the influence of an intraplate thrust zone representing the Alps has given an indication of its possible influence on the European stress field, inducing increased compressions along the axis of indention close to the thrust, and extensional stresses further away.

NUMERICAL MODELLING OF CRUSTAL SHORTENING AND INVERSION IN SEDIMENTARY BASINS

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The deepest parts of thermally equilibrated sedimentary basins in are principle strong because they are underlain by elevated and relatively cold mantle. Yet they respond with crustal shortening and inversion when subjected to compressive tectonic stress. In order to investigate the thermo-mechanical prerequisites for inversion to happen, a plane strain finite element model has been built in which the lithosphere is represented by an elastic-visco-plastic continuum. Modelling results show that regions of relatively low compressional strength must exist for the compression to produce shortening and inversion in the basin centre.
In response to the thickening of sediments and crust Moho subsides in the central parts of the basin. Flexural effects in the upper mantle transfer this Moho-subsidence to the marginal parts of the basin, where marginal troughs are created. Sedimentation in marginal basins synchronous with the inversion is thus explained in this model.
The Late Cretaceous inversion of the Sorgenfrei Tornquist zone and sedimentation in the Norwegian-Danish Basin is consistent with this model.

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LITHOSPHERIC RESPONSE TO TRANSPRESSIONAL PLATE BOUNDARY KINEMATICS

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The crustal adaption to tranpressional oblique convergence has been studied by a variety of authors, and the conditions which produce partitioning or oblique convergence within the crust are beginning to be understood. The behavior of the subjacent lithospheric plate boundary to transpression is still however poorly understood. To improve our understanding of this type of plate boundary regime, we have utilized a 3-D FEM model (TECTON) which allows us to study the role of different rheology, thermal states and time-dependent deformation (e.g. grain size) in controlling the final deformational style. In particular we focus our attention on rheology, plate boundary geometry and temperature variation (temporal and spatial) to see how these affect the shear zone properties and the evolution of a transpressional geometry. The result of this analysis can be applied in the study of different plate boundary zones. including the northern San Andreas fault (USA), Fiordland (New Zealand) and Queen Charlotte fault (Canada).

PREDOCTION AND MODELS OF MODERN CRUCTAL MOVEMENTS IN THE AREAS OF OBJECTS OF NUCLEAR-FUEL CYCLE

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It is well known that the deformations features of geological environment can serve as precursors of seismic events. Complex geophysical and geodetic monitoring allows us to estimate speeds and directions of modern geodinamic horizontal movements, to connect them with periods of preparation of possible seismic events, and to make conclusions about conditions of geological environment in zones of abnormal deformations in the areas where ecologically dangerous nuclear-fuel cycle objects are located.
In 1995-96 three series of GPS-observations were conducted on geodynamic sites in the area of Kalinin and Voronezh power plant. As a result of this work, the technique of GPS-observations was elaborated, initial coordinates and lengths of basic vectors between reference points were obtained and preliminary data on features of modern geodynamic movements in the areas were nuclear power plants are located were received.
The data were correlated with data obtained by regional observation stations located on the East-European platform, thus allowing us to obtain the relative error of basic vectors length definition equal - $1 \cdot 10^{-6}$.

THE ONSET OF EXTENSION DURING LITHOSPHERIC SHORTENING: 2-D DYNAMICAL MODELLING FOR LITHOSPHERIC UNROOTING.

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Although lithospheric collapse is called by several authors in order to explain some controversial geological situation, like the abrupt transition from compression to extension in the Tibetan Plateau and the post-collisional thermal metamorphism in the Betic Arc, the physical mechanism involved in the process is not well known yet. We model the thermo-mechanical evolution of the lithosphere during its shortening and subsequent thickening by a 2-D numerical finite elements model. Our model extends 2000km in width and 700km in depth, thus the coupling between lithosphere and sub-lithospheric mantle is also taken into account in the analysis. Numerical experiments show that the viscous forces associated with lower mantle flow enhance the break-up and downwelling of cold lithospheric roots, which are gravitationally unstable and created as a result of the lithospheric shortening. The results also show that a considerable variation in the dynamic topography of the system occurs after lithospheric collapse. We examine the superficial stress and deformation fields and analyze the conditions leading, immediately after lithospheric collapse, to local extension, eventually coeval to compression. We show how the degree of superficial extension mainly depends on the particular boundary conditions applied to the system. Finally, we show some conclusive results arising from the application of the numerical model.

WAVELET ANALYSIS OF BATHYMETRIC PROFILES FROM MID-ATLANTIC RIDGE: TECTONIC IMPLICATIONS

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Bathymetric profiles of the FAMOUS area are analysed by wavelet transform in order to characterise the shape of the shoulder hills. This numerical method allows the wavelength content to determine and its evolution as a function of the distance to follow. The analysis is applied to profiles of about 70 km long with a 0.1 km sampling interval, in the wavelength range from 1 to 20 km. Three different segments of the rift are selected: a narrow axial valley, a wide axial valley, and an axial dome. The results of the wavelet analysis show that the topography is dominated by a wavelength close to 10-12 km, and that shorter wavelengths are observed in restricted places (the inner corners of the segments and the axial valley). The distribution of secondary wavelengths along the profiles does not reveal a symmetric structure as usually proposed for the oceanic rifts. A complementary analysis, based on the computation of the topographic slope, allows split volcanoes, stair steps, tilted blocks and asymmetric horsts to identify. We conclude that the bathymetry pattern results from tectonic processes rather than from volcanic building. Finally, we propose a structural model where two independent tectonic processes are involved in the genesis of the Mid-Atlantic Ridge shoulders.

EXTENDED THIN SHEET APPROXIMATION (ETSA) FOR GEODYNAMIC APPLICATIONS. EXAMPLES.

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Thin sheet approximations are widely used in geodynamical modelling as they can be manipulated by simple numerical techniques. However, the simplicity of such models leads to strong limitations in their applications. This work presents a new approach to reduce these restrictions. The main goals were to handle all likely boundary conditions and rheology profiles. The set of high asymptotic order depth profiles of velocity and stresses and 2D integrated equations are derived to formulate an extended thin sheet approximation (ETSA). Most previous approaches can be derived by simplification of an extended system under specified boundary conditions. The studies about the applications of different types of boundary conditions have not shown any strong limitations. 2D testing problems for two layer system of Newtonian viscous materials demonstrate a potential of the ETSA. The linear analysis shows good agreement in comparison with exact analytical solutions within a wide range of wavelengths for modelling of Rayleigh-Taylor instability and bending. The investigations of these problems were not possible on the basis of previous generation of thin sheet approaches. The presented examples illustrate the possible applications of ETSA to numerical and analytical investigations of deformations in the significantly layered lithosphere.

INVERSION OF THE GEODYSSEA 94/96 (GPS) DATA FOR CRUSTAL STRAIN AND FAULT SLIP

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We apply the inverse method developed by Spakman and Nyst (presented at this meeting) to the GEODYSSEA (GEODYnamics of South and South East Asia) GPS data set, which consists of 42 relative displacement vectors. The method solves jointly for the deformation gradient field in crustal blocks and slip on active faults bounding the crustal blocks.
Continuous deformation in crustal blocks is parameterized by linear strain in Delaunay triangles. Faults are parameterized by a sequence of line segments. The 4 components of the deformation gradient tensor at each triangle vertex and the components of the slip vector at each fault segment are estimated by the inversion.
The resulting model fits the data well: a variance reduction of about 98 % is obtained with an on average good parameter resolution. In general the resulting slip vectors agree with direction and magnitude of observed slip rates. Strain patterns are generally more difficult to evaluate due to the fact that imaged strain can still relate to slip on unmodelled faults. But, the derived strain field can be understood in the framework of major plate tectonic motions.

GEOLOGICAL STRUCTURE OF THE WESTERN NANKAI CONVERGENT PLATE MARGIN AS REVEALED BY MULTI-CHANNEL SEISMIC REFLECTION DATA

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The Nankai Trough margin is a very important field to evaluate earthquake potentiality of convergent plate margin in that large earthquakes have periodically occurred. We have carried out KR97-04 cruise using R/V "KAIREI", to obtain a high-resolution seismic crustal structure of the Nankai Trough margin off southwestern Japan in July, 1997. During the cruise, we conducted multi-channel seismic (MCS) reflection and OBS refraction experiments. In this paper, we would like to present some MCS data of the western Nankai convergent plate margin and discuss its geological implications. We identified an outstanding seismic reflector with high amplitude in the landward slope of the Trough, which reaches from seafloor to top portion of subducting Philippine Sea Plate (PSP). We interpret the reflector as a possible low-angle seismic thrust fault that seems to be associated with past large earthquake in the the Nankai Trough. There is a lateral variation of the oceanic crustal geometry of the PSP along the Trough, which implies oceanic crustal deformation related to evolution of the Shikoku Basin.

VARIATIONS OF SEISMIC ANISOTROPY IN EUROPEAN MANTLE

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3-D inferences of seismic anisotropy of the continental mantle, as seen by both body and surface waves, broaden our knowledge about structure and development of continents. Complexity of directional dependencies of anisotropic characteristics in various p rovinces (e.g. splitting parameters or P-residual spheres) requires often presence of a multi-layer source of anisotropy with symmetries oriented generally in 3-D. i.e. not only with horizontal or vertical sym metry axes, to account for the observed anisotropy. Distinct spatial variations of P-wave velocities and lateral variations of the particle motion of split shear waves are observed, e.g., around the contact zone of the Saxothuringian and Moldanubian in ce ntral Europe. The variations reflect lateral changes of structure and anisotropy within the deep lithosphere and asthenosphere. A joint interpretation of the P-residual spheres and shear-wave splitting parameters results in a self-consistent anisotropic m od el of the lithosphere with high velocities plunging divergently from the contact of both tectonic units. A strong contribution to the observed anisotropy beneath variscan orogen, coming from the asthenosphere, was detected both by surface and body waves. On the other hand, beneath the Baltic shield, the anisotropy seems to be located predominantly within the lithosphere with the high velocities plunging convergently in tectonic units on both sides of the Protogine zone in southern Sweden. Joint interpreta ti ons of anisotropic findings from different types of seismic waves and frequency ranges, allow us to favor some of anisotropic models of the lithosphere-asthenosphere system and contributes to our understanding of geodynamic processes which formed the cont inents and which are still active.

RECENT STRESS FIELD OF EASTERN MEDITERRANEAN ON THE BASE OF SEISMOLOGICAL DATA ABOUT EARTHQUAKE FOCAL MECHANISMS

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Stress reconstruction of the Eastern Mediterranean crust was executed on the base of the "cataclastic analysis" method of fault slip data sets. Initial data are the seismological data about more 1120 earthquake focal mechanisms (EFM) with the magnitude M_s>4 that took place from 1928 to 1991. The main procedure of the method is the creation of a homogeneous sample of EFM. The main principle in the base of the program algorithm is the main principle of the plasticity theory demanding the positive dissipation energy for true stress tensor. These principle and graphical algorithms of EFM population calculation permit to draw: maps of principal stress axes and izollines of stress state type coefficient. These data determine deviation parameters of stress tensor and permit to calculate the trajectories of maximum and minimum compression stress acting in the horizontal plane and trajectories of underthrust shear stress at the bottom of the crust. Additional assumptions about the properties of the stress field for a free surface permitted to calculate the ratio between isotropic pressure and maximum shear stress. On the base of these parameters areas with different stress state regime were allocated.

MECHANICAL HEATING AND FRACTURING ON DUCTILE SHEAR ZONES IN ASIA

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Plate collision and the phenomenon of intracrustal deformation in Asia with associated mechanical heating and fracturing in the far field is analysed by compiling maps of seismic energy flow and anomalous heat transfer and interpreting these maps by plastic indentation theory. The energy flux of earthquakes is much lower than the observed anomalous thermal flux. Broad bands of increased seismic activity (fracture lines') can be seen traversing the Asian Plate but apart from very localized anomalies the energy transfer is consistently below the $\mu W/m^2$ range. Conversely, anomalous heat transfer in about 40 km wide lineaments (heat lines') has significant values of 20-35 mW/m^2. The thermal energy flux has a maximum in the east Himalaya while the seismic energy flux has its maximum in the Western Himalaya. Fracture lines show the current deformation regime while heat lines (due to a time delay by conduction) report the upper Neogene regime of the ductile crust. An important transition from lateral escape tectonics in the Neogene to cutting of theAsian plate in the Quaternary explains the discrepancy between both data sets.

HEAT GENERATION ASSOCIATED WITH THE COLLISION OF TWO PLATES: THE HIMALAYAN GEOTHERMAL BELT

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An analysis of heat discharged along the c. 3000 km long Himalaya Geothermal Belt (HGB) has shown that anomalous heat transfer is concentrated along 30 -50 km wide heat bands' which are associated with at least 600 geothermal systems. Neglecting anomalous conductive losses within heat bands the anomalous heat transfer is of the order of 20 - 35 mW/m^2 as assessed by transfer of geothermal fluids to the surface. Computed geotherms indicate that partial melting at c. 30 to 50 km depth can occur within the heat bands. Heat bands are interpreted in the mathematical treatment as heat lines' which are equivalent to slip lines caused by plastic deformation of the ductile crust. Conversion of the mechanical energy of the collision into heat raises the average heat flow on heat lines, locally by up to 55 mW/m^2 (normalized on a 40 km wide heat band). This is sufficient to cause granitization without additional heat input by mantle melts and explains the rate of heating observed in geothermal systems. The asymmetry of heat discharged in the HGB (heat bands in the eastern Himalaya transfer about 2-3 times more heat than the entire western Himalaya) can also be explained by a counterclockwise rotational penetration of the Indian Plate into Asia.

Results of studies of the lithosphere in the transition zone from the Asian continent to the Pacific ocean by the system of geotraverses

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Research was carried out along three geotraverse of the lithosphere made on the base of complex interpretation of geological and geophysical data. The first geotraverse across the structures of the Japan Sea was prepared jointly with Japanese scientists. The second geotraverse across the Philippine Sea carried out jointly with Chinese and Japanese specialists. The third geotraverse being under preparation now runs across the Sea of Okhotsk. Using seismological, geothermal and electromagnetic methods the asthenospheric layer is distinguished in the upper mantle of the transitional zone. This layer is more fully manifested under tectonical active structures such as interarc troughs and deep basins of marginal seas. The top of the asthenosphere varies in depth from 30 km under Neogene basins to 50-80 km beneath Paleogene basins. Under interarc basins of island arcs the anomalous mantle reaches the crust. The base of the deep basins comprises rift structures associated with upwelling of the asthenosphere causing extension stresses in the lithosphere and magmatic activity.
The following relationship has been elucidated: upwelling of the asthenosphere in the upper mantle; magma chambers in the crust; rift structures on the surface; tholeiite eruption and hydrothermal activity with sulphide deposits.

SUBDUCTION OF A MID-OCEAN RIDGE BENEATH THE NORTHEAST PACIFIC MARGIN OF NORTH AMERICA

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The Cenozoic evolution of the NE Pacific and Western North America provides an example of the interaction of a ridge with a suduction zone. Three linked phenomena were important at this plate boundary: (1) The direction of mantle flow shifted at 65-60 Ma from nearly perpendicular to nearly parallel to the coast. This slowed subduction, promoted the activation of the passive subducting Kula-Farallon ridge, and generated extensive Eocene basalts along the Oregon and Washington coast. (2) Subduction of the mid-ocean ridge beneath present-day Gulf of Calif. 45-40 Ma broke the Farallon slab beneath W. N. Amer. and led to separation of the Baja Peninsula from the mainland. (3) Westward drift of both the N. Amer. and Pacific plates relative to the deep, hot root of the mid-ocean ridge helps explain several tectonic and magmatic phenomena, including uplift and extension of the Basin and Range province, rifting of the Great Valley of Calif., and volcanism of the Western Cascades magmatic arc.

THE SIGNIFICANCE OF DISSIPATIVE HEATING IN DELAMINATION AND SUBDUCTION PROCESSES

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The phenomena of delamination and the attendant subduction of the mantle lithosphere are important in understanding convergent tectonic processes. Viscous heating has not been generally appreciated because of the high numerical resolution required. We have carried out simulations focussing on the effects of shear heating in the continental lithosphere, driven by both thermal and compositional buoyancy forces. The dynamics are governed by the conservation equations of mass, momentum, energy, and chemical composition in a two dimensional cartesian geometry, and are solved using a finite-difference model. The ductile rheology of the crust and the mantle is combined with a quasi brittle rheology to an effective rheology. Comparing a model with dissipation number $Di \approx 0.3$ to a model with $Di = 0$ for the same amount of material transport clearly shows the effect of the dissipative heating. It leads to excess temperatures of $\approx 400°C$ in the subducting lithospheric root during the delamination phase. We conclude that viscous dissipation is an important element in studies of thermo-mechanical processes of the crust-lithosphere-mantle system.

POST-SEISMIC DEFORMATION IN A SPHERICAL GEOMETRY WITH SOME APPLICATIONS TO REAL EVENTS

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Co-seismic and post-seismic deformation following large earthquakes is modeled by means of multilayered, viscoelastic Earth models based on PREM. The novelty of our approach stands on the usage of a fully analytical scheme based on normal mode theory that allows to deal with some of the complexities of the real Earth, such as lithospheric and mantle layering, sphericity and self-gravitation. For both dip-slip and strike-slip sources, we obtain that elastic layering of the lithosphere is necessary for the modelling of realistic patterns of post-seismic deformation. Sensitivity analyses are performed in order to study the impact of rigidity and density layering on the deformation pattern due to different sources. The viscosity structure of the mantle has a major influence on post-seismic deformation in the far field, at distances from the epicenter of the order of 100 km. Our method is applied to the modelling of the deformation pattern that has followed real seismic events. Our findings are key for a correct interpretation of VLBI, GPS and SAR data in seismogenic regions.

LITHOSPHERIC STRUCTURE OF THE ALBORAN BASIN (W-MEDITERRANEAN): RESULTS FROM 3D MODELING OF GRAVITY, HEAT FLOW AND ELEVATION DATA.

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The Alboran sea basin is an E-W elongated Neogene extensional basin located at the westernmost Mediterranean at the Iberia-Africa convergent plate boundary. The basin is surrounded to the North and South by the Betic-Rifean Cordillera and it is closed to the West by the Gibraltar arc. whereas to the East it opens to the deep waters of the South Balearic Basin. Previous geophysical studies show that the maximum crustal thickness in the region is located beneath the Central Betics (up to 38 km) with a rapid attenuation towards the coast, where the crust is 22-23 km thick. However, in the center of the basin, the Moho topography is not well imaged. Recent heat flow measurements suggest that the lithosphere thins towards the center and east of the basin where values up to 115 mWm^{-2} were reached. To derive the crustal and lithospheric structure of the basin and its margins we have performed a 3D gravity model constrained by heat-flow and elevation data. The obtained depth to the Moho shows a crustal thinning from the Betics and Rif (34-36 km) towards the center (18 km) and east (10 km) of the Alboran basin. The lithospheric thickness varies from 140 km in the Gibraltar arc to less than 50 km in the east Alboran basin. The lateral variations of crustal and lithospheric thickness obtained from our 3D model show different patterns, indicating that this plate boundary underwent a complex deformation during the Tertiary.

Geophysical model of contracting Earth and natural processes.

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The geophysical features of the Earth are being created under influence of the forces, related to the masses, energy impulses, electromagnetic and nuclear weak and strong interactions of the bodies in the Sun-Earth system. Calculations show that quasiperiodic and non-stationary impulses of Sun energy can induce the contraction of the Earth as much as 3,2 cm in 100 years, so in $4.5*10^9$ years of the Earth's life its radius can be decreased by nearly 1600 km, and the annual deformation along the radius can reach $5*10^{-11}$. The difference between the deformation increase and decrease due to the change of daily Earth rotation can change deformation by $6*10^{-8}$ .Variation of the Earth's electromagnetic momentum, related to the redistribution of the electric current at the core-mantle interface, can induce the deformation gradient 10^{-9} -10^{-6} and the various alteration of the inner strata radius. To summarize briefly, the geophysical model of the contractible Earth can be envisioned as consisting of the three blocks. The Northern and Southern parts are presented the spherical lenses, formed by the Earth radius at the points, where the instant axis of rotation crosses the Earth's surface at the North and South. The wedge-like part of the model is situated between these lenses. Space-time fluctuation of the model explains the nature of the earthquakes, Chandler's pole oscillations, frequency of the own and forced Earth perturbations, climate and ocean level variations, etc.

3-D THERMAL MODELING OF THE SOUTHERN CALIFORNIAN UPPER MANTLE: THE TECTONIC HISTORY OF MICROPLATES

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Offshore the coast of southern California, remnants of the Monterey and Arguello microplates are preserved. Various scenarios have been suggested in the past for the tectonic evolution of these microplates during the Miocene. We try to discriminate between two end-members of these scenarios, using numerical simulations to predict the 3-D temperature structure of the upper mantle.
The scenarios have different implications for the behaviour of a ridge that approaches a trench. In the first scenario, the microplates subduct almost totally, whereas subduction of microplates is absent in the second scenario, leading to the opening of a shallow window in the slab at about 20 Ma.
Comparing our synthetic models to heat flow data, we find that both scenarios fit the surface heat flow values very well. Also, our results are consistent with large-scale features in tomographic images. Local deviations from heat flow data and tomographic results are ascribed to post-Miocene tectonic events not included in the modeling. After 20 m.y. of model evolution, there are still some small thermal differences between the upper mantles of the two scenarios. However, these differences are too small to discriminate between the models based on the currently available tomographic results.

The Importance of Thermal-Mechanical Coupling in Necking Process of an Elasto-Viscoplastic Lithosphere

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Necking of the lithosphere undoubtedly involves complex nonlinear thermal-mechanical feedback mechanisms, especially in view of an elasto-viscoplastic rheology, which offers many opportunities for thermal instabilities and bifurcations to develop. Yet these aspects have been largely ignored in previous modelling of lithospheric processes. We have included both a temperature-dependent non-Newtonian viscoelastic rheology and a temperature-dependent viscoelastic-plastic rheology in a self-consistent study of lithospheric necking processes in continents. Upon extension, localized deformation takes place by mechanical heating triggered by the rapid energy transfer of the initially stored elastic energy associated with the tectonics. For rheological parameters characteristic of the lithosphere, this process can occur within 10**5 years. We apply this model to the young back-arc spreading in the New Zealand-Kermadec-Tonga subduction system.

SE6 Post-glacial rebound and its influence on sea level, crustal deformation and gravity: new observations, modelling results and initiatives

Convener: Mitrovica, J.X.
Co-Convener: Vermeersen, L.L.

Glacial Isostatic Adjustment From Space Geodesy

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VLBI, SLR, and GPS measurements from 1976 to 1997 are providing information about glacial isostatic adjustment, including:

(1) Onsala (Sweden) and Algonquin Park (Ontario) are rising at 2.5 mm/yr, reflecting rebound in response to the disappearance of, respectively, the Ice-age Laurentide and Fennoscandian ice sheets;

(2) Haystack (Massachusetts) is neither rising nor falling and Greenbelt (Maryland) is falling at 1 mm/yr, indicating that the lithospheric forebulge around the Laurentide ice sheet is hardly collapsing at all; and

(3) Onsala and Algonquin Park are moving away from the ice sheet centers at 1 mm/yr, but the horizontal motion generated by glacial isostatic adjustment is minuscule at all other geodetic sites on the North American and Eurasian plates.

Model ICE4G-VM1 [Peltier, 1994] predicts observations (1) and (3) but disagrees with observation (2). Model ICE4G*-VM2 [Peltier, 1996] predicts observations (1) and (2) but disagrees with observation (3). The three observations together point toward a model with the ICE4G* ice history, the VM2 mantle viscosity, and an elastic lithosphere thicker than the 120 km assumed in Peltier [1996]. We will construct models exploring different parameters.

CRUSTAL DEFORMATIONS RELATED TO POST-GLACIAL REBOUND AND SEA LEVEL CHANGES IN THE VARNA BAY (NE BULGARIA)

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The post-glacial rebound and the contemporary history of the development of the Varna Bay is a subject of the investigation. The tectonics processes, the eustatic changes, the disastrous manifestations as result of a seismicity, gravity, sediment accumulation, erosion, abrasion are of a great importance for the recent characteristics of the studied territory. The influence of the anthropogenic activity also is taken in account.

The Varna Bay has a great importance for the politic, economical and cultural development of the country. The geological study of the territory could be used in the next geoenvironmental works.

3D VISCOSITY VARIATIONS AND POST-GLACIAL REBOUND

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Post-glacial rebound effects on horizontal and vertical deformation rates are commonly studied under the assumption of a spherical simmetry. It has been established as well that lateral variations of the properties of the lithosphere and mantle can produce detectable effects on the deformation, especially in the proximity of the border of the glacial load. Previous studies usually approach this problem combining radial and longitudinal variations: in this work we show some results of a fully 3D finite element model with a flat geometry. We study simple geometric configurations in order to establish how the response to the glacial rebound is affected by the presence of sharp variations of the thickness of the lithosphere. In a regional scale, like the Fennoscandian shield region, our results can be useful to estimate the second-order effects of the 3D variations in relation to the results of lateral uniform models.

DETERMINATIONS OF MANTLE VISCOSITY AND ICE HISTORY MODEL PARAMETERS FROM PROJECT BIFROST GPS DATA

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Project BIFROST (Baseline Inferences for Fennoscandian Rebound Observations, Sea-Level, and Tectonics) has been acquiring Global Positioning System (GPS) data since August, 1993. The formal uncertainties in determinations of crustal deformation rates are approximately 1-2 mm/yr for the vertical component of velocity and about a factor of 3 smaller for the horizontal components. These data give us an unprecedented picture, independent from sea-level data, of the present-day three-dimensional regional crustal motions associated with glacial isostatic adjustment. Preliminary inversions of vertical rates for the mantle viscosity profile indicate a significantly weak upper-mantle viscosity, but the post-fit residuals are systematic and are probably our first indication of ice model errors. We will describe the BIFROST GPS network and present the determinations of crustal velocity. We will describe our inversions, and discuss the influence of ice model errors. We will then present our preliminary investigation into updated ice/viscosity models.

MULTI-LAYER ANALYTICAL EARTH MODELS OF SEA LEVEL CHANGES INDUCED BY PRESENT-DAY GLACIAL INSTABILITY AND POST-GLACIAL REBOUND

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A newly developed analytical model for dealing with a general radially stratified, self-gravitating, incompressible viscoelastic Maxwell Earth model is presented for evaluating the global changes in sea level due to Pleistocene deglaciation and present-day instabilities in Antarctica and Greenland. We compare sea level predictions obtained by means of a variety of models carrying a different number of layers in the lithosphere and mantle. We show the impact of density and viscosity stratification on sea-level changes induced by Pleistocene deglaciation both in the near and far field of deglaciated areas. The models on present-day instabilities in Antarctica and Greenland are based on elastically stratified earth models. The perturbation in the geoid and the dynamic topography due to meltwater redistribution are also considered separately from sea-level changes, in order to obtain a deeper insight into the physics of the process.

THE POST-GLACIAL SHORELINE DISPLACEMENT ON SVALBARD INDICATES A HIGH VISCOSITY MANTLE.

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The deglaciation of the last ice age on Svalbard is relatively well established by observations of radiocarbon-dated marginal moraines. Post-glacial shoreline displacement curves are constructed for various locations over the area; of which 11 are used here. The theoretical sea level changes are calculated with an earth model with layered viscosity, overlain by an elastic lithosphere of constant thickness. The modelling is done with two different mantle rheology models, 1) a low viscosity asthenosphere and 2) a uniform mantle viscosity. The first model has the same rheology that gave the best fit with the observations in Fennoscandia, a 75 km asthenosphere of viscosity 1.3 x 10^{19} Pa s overlying a mantle of viscosity 10^{21} Pa s. The second model has a uniform mantle of viscosity 10^{21} Pa s. The low viscosity asthenosphere model will, of course, give a faster post-glacial uplift than the uniform model. The observed sea level changes show that there has been a slow uplift in the area, indicating a high mantle viscosity. In contrast to Fennoscandia, the uniform model gives the best fit to the sea level data.

THE ISOSTATIC MODEL AND DEEP STRUCTURE OF ANTARCTICA

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The two isostatic models of Antarctica, which differ by the mechanism of compensation of ice load, are represented.
The first model assumes full local compensation of total load by Airy scheme. The level of compensation is the Moho surface.
The second one based on the general ideas about evolution of the ancient platform in the situation of the beginnings and development of glaciation. In this case the part of load, connected with the relief of the glacier bed, is compensated locally, and the ice load is compensated regionally.
For the constructing of both models seismic data (DSS profiles) for Antarctica was used.
The methodical base of the work is spectral statistical analysis.
The heights of the glacier bed and the surface of the glacier data was collected. The corresponding maps in figures was produced. On the base of the isostatic modelling the estimation of the Moho depth was made. The difference between the Moho depths, obtained in this work, and early published ones are about 5 - 7 km. The map of isostatic gravity anomalies was constracted.
The global component of the anomalous gravity field, which caused by the density inhomogenieties in the mantle on the effective depths 900 km was obtained. The maps of the global and local components of the anomalous gravity fields was constructed.

INSTABILITY OF COMPRESSIBLE VISCOELASTIC MODELS

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It is usually assumed that the Maxwell viscoelastic response of Earth models to surface loads with the Heaviside time dependence reaches an isostatic equilibrium after a sufficiently long time. It was analytically shown that it is valid for a homogeneous incompressible sphere. It seems to be not commonly known that it can be analytically shown that it is not valid for a homogeneous compressible sphere. We present the full spectrum of such a model, computed both from the initial-value approach and from the analytical solutions; corresponding unstable response is rising at the time scale of $O(10^4\,\mathrm{yr})$. This feature of instability is kept by any compressible spherical layer with constant parameters, and also by models built up from such layers; thus, the isostatic equilibrium state cannot be reached by a viscoelastic response for layered compressible models. The compressible fluid in the isostatic equilibrium can be stable if density distribution satisfies the Adams-Williamson equation. The response of the compressible sphere with such density distribution is numerically shown to be perfectly stable. Conclusion: viscoelastic responses of compressible models to surface loads are stable only when the density models themselves are stable. Simplified models with few homogeneous layers are inadequate in viscoelastic modelling with finite bulk modulus.

MODELING ISOSTATIC RESPONSES OF SHORT TIME AND DISTANCE SCALES: THE RECORD IN THE GULF OF MAINE

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Global-scale models of isostatic response to ice-sheet retreat fail to account for the relative sea-level curve observed in the northern Gulf of Maine. Radiocarbon-dated in situ sea-level indicators record a more complex and geologically interesting local response. Deglacial highstand occurred 13.5 ka at 70 m near the present Maine coast, relative lowstand at 10.8 ka near -55 m, rapid rise to a stillstand near -20 m from 10-8 ka, followed by rapid rise, slowing toward the present. The 11-8 ka record has been interpreted as passage of a small lateral-scale marginal bulge with amplitude up to 25 m. Similar responses are observed in sea-level records of the Scotian Shelf and St. Lawrence Estuary, and in lake-tilt records in central Maine, interpreted as progressive passage to the north and decay of a marginal bulge. Published numerical models fail to account for this short-term and small-scale response. These models routinely assume elastic lithosphere deformation and viscous mantle deformation, that move the forebulge farther south. We improved the fit by assuming an elastic-viscoplastic lithosphere on a viscous mantle. We fitted a numerical solution to an analytical solution for steady-state deformation beyond an ice sheet treated as a slab of constant thickness. Then we obtained a numerical solution for the actual distributed load of the Laurentide Ice Sheet in the Gulf of Maine at the last glacial maximum, as determined from geologic data. Finally, we obtained a numerical time-dependent solution for changing distributed ice and water loads during and after deglaciation. Material constants for the lithosphere and mantle were adjusted to give the best theoretical fit to the field data.

PATAGONIAN LITTLE ICE AGE REBOUND

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Observations of the Northern and Southern Patagonian icefields in the southernmost Andean Cordillera indicate that between 140 - 380 km^3 of continental ice has been lost by mass wasting during the years 1944 - 1985. A number of less-quantitative observations strongly suggest that such a pattern of deterioration began between AD 1850 and 1900. Glacial moraine deposits suggest 3 additional episodes of regional glacial advancement during the mid to late-Holocene. We construct a late-Pleistocene and Holocene glacial load history and demonstrate the sensitivity of any geodetic measurement of present-day crustal uplift to the Little Ice Age and its timing and total mass change. If the viscosity of the mantle is one order of magnitude smaller than that characterizing Fennoscandia, then the uplift adjacent to the Southern Patagonian icefield is predicted to be on the order of 1 - 1.5 cm / yr. Geologically recent (0 - 12 Ma) northward migration of the Chile Triple Junction, and the slab window left in the wake of that migration, might be cause for such an a priori lower estimate of mantle viscosity. Neoglaciation of Patagonia during Europe's "Dark Ages" (circa AD 400 - 1000) might also contribute an additional 10 - 30 % to the predicted uplift signal. The observations of Masuma Aniya and colleagues pertaining to the 20th Century rate of glacial demise are crucial to the model. These rates, extrapolated back into the mid to late 19th Century, are the primary source for the prediction of rapid crustal deformation at the present-day.

POSTGLACIAL REBOUND IN THE NORTHERN CASCADIA SUBDUCTION ZONE

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Southwestern British Columbia and northwestern Washington State are tectonically complex regions that include the northern portions of the Cascadia subduction zone, which features subduction of relatively young (≈6 Ma) oceanic crust, a low heat flow forearc and high heat flow volcanic arc. Prior postglacial rebound models assume that a rheological structure (lithospheric thickness, mantle viscosity profile) suitable for explaining relative sea level variations observed on the stable Archean craton of eastern North America is also appropriate to Cascadia. Available relative sea level observations from this area, however, exhibit extremely rapid uplift, with a response time perhaps of the order of 500 years, implying a mantle viscosity substantially lower than the nominal value of 10^{21} Pa·s frequently inferred for the upper mantle of eastern North America. A first-order refinement of a global model previously applied to this area reveals the need for an improved representation of the ice sheet in this area and a mantle viscosity of 10^{19} Pa·s or smaller. More detailed reconstructions, when applied to observed tilting of features related to proglacial lakes in the Puget Sound area, indicates substantial tradeoffs between mantle viscosity and lithospheric thickness, although lithospheric thicknesses of only a few 10's of km and mantle viscosities $\leq 10^{20}$ Pa·s seem to be a robust outcome of this study. Incorporation of lateral Earth structure in future modelling efforts would help refine these results.

UPPER MANTLE LATERAL VISCOSITY VARIATIONS AND POSTGLACIAL REBOUND: APPLICATION TO THE BARENTS SEA

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We investigate the effect on present-day observables of glacial isostatic adjustment. We assume that the asthenospheric viscosity is varying in the lateral direction, thus, we model a simplified scenario of a continental margin with viscosities in the uppermost mantle becoming stiffer towards the interior of the continent. Our results indicate that a variety of geodetic signatures related to the glacial isostatic adjustment process are capable to resolve the proposed lateral structure within the observational uncertainties. In particular, relative sea-level changes, present-day velocities and gravity anomalies from the marginal areas of the formerly glaciated regions have the potential to distinguish between different rheologies. The application of our modeling to the deglaciation of the Barents Sea shows for the first time that a realistic space-time history of the Late Pleistocene glacial cycle can provide information on the lateral structure of the uppermost mantle.

IMPLICATIONS OF PLEISTOCENE GLACIATION OF THE TIBETAN PLATEAU ON PRESENT GEODETIC OBSERVABLES

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The effect on present observable parameters of a Tibetan Plateau glaciation corresponding to the Late Pleistocene glacial maximum at about 21,000 yr B.P. has been investigated. Different ice models have been published for the region and both minimalistic and maximalistic models are considered. These bounds permit the prediction of implications arising from the disintegration of an ice sheet on present uplift rates and gravity anomalies. The large ice sheet models can contribute up to 7 mm/yr of present vertical uplift and 2 mm/yr of horizontal extension, with the former value able to explain more than 50 percent of the observed uplift in central Tibet. The peak free-air gravity anomaly arising from the deglaciation would be around −5.4 mGal. In contrast, the smaller ice sheet models do not contribute significantly to the signals of present uplift and gravity anomalies. Modern geodetic measurements therefore have the potential to constrain the Late Pleistocene glaciation of the Tibetan Plateau. Assuming a large ice sheet over the Tibetan Plateau the disintegration can contribute up to 6 m of eustatic sea-level rise.

TESTS OF GLACIAL REBOUND MODELS FOR FENNOSCANDINAVIA BASED ON INSTRUMENTED SEA- AND LAKE-LEVEL RECORDS

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Rebound models are usually based on geological indicators of sea level change. The disadvantage is that the observations are of relatively low accuracy and inhomogeneous in nature. Advantage of mareograph records is that the estimates of present sea level change are of a relatively high precision and homogeneous. Their drawback is that the record is short and that other signals may dominate the record. In the case of Scandinavia the mareograph and lake level records are potentially important for several reasons, including the good coherence of long-period signals in the sea levels of the Baltic Sea. A comparison of a recent analysis of the mareograph and lake data with rebound models constrained by geological data confirms that the two data types yield consistent information on mantle rheology and ice-model parameters. It also leads to an estimate of present-day eustatic sea-level change.

PALEOMAGNETISM OF MISSISSIPPI VALLEY-TYPE MINERALIZATION IN SOUTHERN FRANCE AND CENOZOIC OROGENESIS

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A temporal relationship between orogenesis, large scale crustal fluid migration, dolomitization, and MVT mineralization has been inferred from geochemistry, paleomagnetism and isotopic dating in several orogenic belts and adjacent basins throughout the world. The relationship is tested here by paleomagnetic analysis of carbonates containing MVT mineralization from four locations (Villemagne, Trèves, Gatuzières and Le Bleymard) in the Cévennes region of southern France. The area has a complex tectonic history, having been subjected to both Hercynian and Pyrenneen deformation. AF and thermal demagnetization isolated a northerly, steep downward remanent remagnetization that, after partial untilting for north-south Eocene compression, falls close to the expected Eocene direction for western Europe, coeval to orogenesis in the area. Although the relationship between remagnetization and mineralization is not perfectly demonstrated, these data suggest that all or some of the MVT mineralization in this region is of Eocene age and conforms to the general model for crustal fluid migration controlled by orogenesis.

SE6

RECENT ADVANCES IN MODELLING POSTGLACIAL SEA-LEVEL VARIATIONS

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The sea-level equation first described by Farrell and Clark [*Geophys. J. astro. Soc*, 1976] governs the redistribution of surface water in response to ice mass fluctuations on a viscoelastic planet. The theory, applied to the melting of the Late Pleistocene ice complexes, successfully predicts a number of features that are evident in the global sea-level record. Regardless of this success, however, a number of recent articles have addressed two assumptions explicit in the original sea-level theory: the continent function defining the geographic boundary of the ocean load was assumed to be time independent and the influence of Earth rotation was neglected. These studies have shown that the magnitude of the previously neglected effects is large enough to alter inferences of glacial isostatic adjustment (GIA) model parameters. In this presentation I will discuss these recent improvements to the sea-level theory and touch upon the importance of these mechanisms when applying rebound models to constrain mantle viscosity and ice sheet parameters. I will also describe a very recent finding that the sea-level equation breaks down in certain geographic locations during the deglaciation period. I will introduce a modified sea-level equation that overcomes this problem and will discuss the significance of the new theory with regard to the application of constraining models of the GIA process.

JOINT INVERSIONS FOR MANTLE VISCOSITY

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We report here on ongoing efforts to constrain the radial viscosity profile using inverse procedures applied simultaneously to data associated with glacial isostatic adjustment (GIA) and mantle convection. In previous work [Forte & Mitrovica, *Geophys. Res. Lett.*, 1996; Mitrovica & Forte, *J. Geophys. Res.*, 1997] our dataset included decay times associated with post-glacial relative sea level (RSL) variations at sites in previously glaciated regions (Laurentia and Fennoscandia) and long-wavelength free-air gravity anomalies. We found that both these data sets may be reconciled using a single profile of viscosity characterized by a significant increase ($\sim 1-2$ orders of magnitude), with depth, in the mantle. In more recent work we have extended these analyses to include an improved and much larger data base of GIA observables, as well as seismic and geodetic constraints on the topography at the CMB and 670 km depth. We will report on whether lateral heterogeneities in rheology need to be invoked to reconcile the totality of the GIA data set. Furthermore, we will summarize features common to all viscosity profiles which simultaneously satisfy the GIA and convection observables. We have found, for example, that while a large increase of viscosity, with depth, is required to fit the data, the form of this increase is strongly constrained.

GLACIAL ISOSTASY, EUSTASY, GEOID DEFORMATION, ROTATION, CIRCULATION AND PALEOSEISMICITY

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The waxing and vanishing of land ice sheets are driven by climate. It generates and drives a number of gedynamic processes. The water masses stored in the ice are taken from the sea, by that driving glacial eustatic sea level changes. The lowering and subsequent rise in sea level affects the earth rate of rotation; a glacial acceleration followed by a postglacial deceleration. The rotational changes drive variations in ocean circulation affecting distribution of heat and water masses. The glacial loading deforms the geoid relief not only in the ice proximity but also in the far field. Global loading models are often discussed. The Fennoscandian glacial deformation and rebound amounts to 830 m with a simingly total compensation by lateral mass movements in the asthenosphere (leaving little or no room for deeper loading adjustments). The deglaciation period with rates of uplift in the order of some 10 cm per year is in Sweden associated with a very high seismic activity both in seismic recurrance and in magnitudes of events. By about 6000-5000 years BP the glacial eustatic sea level seems to have been restored and the general deceleration finished. After ~5000 BP, the redistribution of energy and water to dominates.

MODELLING OF LAND EMERGENCE AND SECULAR GRAVITY CHANGE IN FENNOSCANDIA

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A classical problem of geodynamics is the inversion the *glacial-isostatic adjustment* of Fennoscandia in terms of the viscoelastic stratification in the earth's mantle below it. In our study, we use an n-layer, incompressible *Maxwell-viscoelastic* half-space (Wolf, 1985) as the earth model and a time-dependent distribution of discs as the load model. The latter is tuned to simulate closely the deglaciation history in southern Finland and central Sweden. The observational data consist of the *post-glacial land emergence* in Ångermanland (Sweden) and Helsinki (Finland) and the *present rate of land emergence* in Vaasa and Helsinki (both Finland). The joint inversion of the data places improved bounds on the viscoelastic stratification of the earth's mantle in this region. The best-fitting earth model has (1) an elastic lithosphere with 65 km in thickness, (2) a 100 km-thick viscoelastic asthenosphere with a viscosity of 1.9×10^{19} Pa s, and (3) a viscoelastic upper mantle with a viscosity of 1.2×10^{21} Pa s. A further constraint is provided by measurements of the *rate of relative secular gravity change* along the profiles Vaasa–Äänekoski and Kemiö–Virolahti (both Finland), which have returned ~ -0.52 μGal a^{-1} and ~ -0.42 μGal a^{-1}, respectively. Using the best fitting earth model, the predictions deviate from these values by ~6 per cent and ~17 per cent in magnitude, respectively.

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JOINT MANTLE VISCOSITY INVERSIONS OF POLAR WANDER AND GEOID CHANGES INDUCED BY PLEISTOCENE AND CONTEMPORARY ICE MASS VARIATIONS

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Post-glacial rebound due to Pleistocene Ice Age cycles and contemporary changes in the distribution of ice and water over the Earth's surface are, at least partly, responsible for the secular shift of the Earth's rotation axis and changes in the low degree zonal harmonics of the geoid. The error bounds of the measurements of secular polar wander and on zonal harmonics 2 - 5 of the present-day geoidal variations have become small enough so that they are useful in joint inversions for the radial mantle viscosity profile.
We show results from joint inversions for the mean upper and lower mantle viscosities for a set of Pleistocene and Holocene ice mass forcings, and discuss the many uncertainties and its impact on the inversion results that exist in the assumptions on the loads.

GRAVITATIONAL STABILITY OF VISCOELASTIC RELAXATION MODELS

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Viscoelastic relaxation models as used in post-glacial rebound studies can show various kinds of inherent instabilities. Examples include instabilities due to inversions in the (initial) radial density profile, instabilities occurring when the elastic Lame parameters are too small to counteract the destabilising effects of self-gravitation, and instabilities due to density perturbations in Earth models which have a marginally stable radial density profile.
We present an overview of these various categories of instabilities, and their potential importance for elastic, viscoelastic incompressible and viscoelastic compressible self-gravitating spherical Earth models. Special attention is devoted to the influence of discrete layering on the occurrence, strengths and time scales of unstable relaxation modes in models with a compressible Maxwell rheology.

ANTARCTIC ELEVATION CHANGE 1992-1996: IMPLICATIONS FOR MASS BALANCE

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The mass balance of the Antarctic Ice Sheet is uncertain to +/- 400 Gt/yr and is the largest uncertainty in determining the present observed rise of mean sea level. Although sparse glaciological observations of accumulation and outflow indicate that the balance may be positive by as much as 400 Gt/yr, an increasing Ice Sheet mass makes difficult closing the present sea level rise budget. In this paper we report on the elevation changes observed with the ERS altimeters of 60% of the interior of the Antarctic Ice Sheet. The observed change is gently negative, equivalent to -67 +/- 37 Gt yr, with significant changes occuring only in West Antarctica. The relationship between elevation change and mass change is subtle, because the elevation is differently sensitive to short and long term changes in accumulation rate as a result of the densification in the near surface. We present evidence that much of the observed elevation change is due to short-term, short-scale accumulation fluctuations, and in consequence the sheet is close to balance. We conclude it is very unlikely that the Antarctic Ice Sheet has been a substantial source of ocean mass this century.

ABSOLUTE GRAVITY AND GPS MEASUREMENTS IN GREENLAND

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Changes in the distribution and volume of ice in Greenland causes vertical crustal motion of up to several mm/yr or more around the edges of the ice sheet. The viscoelastic response of the earth to past changes in ice loading could cause vertical motion rates that are of the same order. These viscoelastic effects must be removed before the observations can be used to help constrain the mass balance of the ice caps. This can be done by combining vertical motion measurements with simultaneous observations of gravity. We have begun a multi-year, NASA/NOAA-funded program to make simultaneous measurements of absolute gravity and crustal motion (using continuously-operating GPS receivers) at bedrock sites around the edges of the Greenland Ice Sheet. We currently have 2.5 years of GPS measurements and 3 occupations with absolute gravity from the west coast. In this talk, we will describe the project, the theoretical motivations, and speculate on the interpretation of the preliminary data.

SE7 Variations in the Earth's rotation: implications for the dynamics and structure of the mantle and for global change processes

Convener: Sabadini, R.
Co-Convener: O'Connell, R.J.

EFFECTS OF SUBDUCTIONS AND TRENDS IN SEISMICALLY-INDUCED ROTATIONAL VARIATIONS

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Seismically-induced rotational changes show statistically significant trends. The rotation axis is moved preferentially towards a well-defined direction (~ 140° E) and the Earth's oblateness is systematically decreased. Our purpose is to employ the static dislocation theory to ascertain the origin of these two remarkable trends. We find that these tendencies are operating even on a yearly time-scale, and we explain their nature by means of simple geometrical and physical arguments. The trend of the pole towards 140° E is essentially due to the seismicity which characterizes the Western Pacific subduction zones. We also address the potential effects of aseismic mass rearrangement at subduction zones on the secular drift of the pole. Our findings, based on a simple model of steady-state subduction, show that in the two last decades this process substantially acts to counterbalance the polar drift due to global seismic activity. We verify that this balance between earthquake- and subduction-induced rotational signatures also characterizes the time-variations of the dynamic oblateness of the Earth. From these results, which may potentially have some impact on the interpretation of long-term polar motion, we conclude that the pole of rotation cannot be significantly perturbed by tectonic motions on a decade time-scale.

"Earth Orientation Parameters measured by Space Geodesy Techniques"

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The Earth's rotation study has involved the scientific community since at least a couple of centuries. This is certainly a consequence of the complexity of the Earth system interactions and therefore a complete discussion involves an interdisciplinary effort between different sections of Earth and planetary sciences. In particular the geophysical community is demanding more and more accurate measurements of geodetic parameters in order to correctly interpret them. The space geodetic techniques are currently offering a huge amount of products diffused by several international services (e.g. IERS and IGS) with different levels of precision and accuracies. We will compare different EOP time series estimated with Satellite Laser Ranging (SLR), Very Long Baseline Interferometry (VLBI) and Global Positioning System (GPS) and combine their results taking care of reference frame biases. The discussion will be focused on the sensitivity of the different space geodetic techniques to the EOP, separating differential systematic errors from random errors and setting the boundaries for the interpretation of the visible geophysical processes.

MOVEMENT OF EARTH'S INSTANT POLE OF ROTATION

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It is considered, that the movement of a pole received from astronomical supervi sion over change of breadth, belongs only to Earth's an instant pole of rotation (Chandler 's motion). The researches, carried out(spent) by us, of a trajectory of movement of a pole have shown, that it not so. That is accepted for a trajectory of movement of an instant pole of rota tion of the Earth, actually, represents set of movements of an axis of the world (a polar ax is of inertia of the Earth) and the axis of Earth's instant pole of rotation (Chandler's motion). We establish the physical nature of Chandler's motion and mechanism of excitation and maintenance of oscillatory movement. The cause-effect connections of the found out movement of a polar axis of inertia of the Earth (axis of the World) and Earth's instant pole of rotation with the material World surrounding the Earth. We establish the connection between movement of Ear th's instant pole of rotation and the irregularity of rotation of the Earth.

MULTIPLE EPISODES OF RAPID TRUE POLAR WANDER IN VENDIAN-CAMBRIAN TIME

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Although paleomagnetic apparent polar wander (APW) paths should contain components of between-plate motions as well as true polar wander (TPW), the latter fraction is usually assumed to be zero, except for specifically proposed intervals of rapid TPW. For pre-Mesozoic time, these hypotheses are difficult to test quantitatively because the pre-Mesozic geological record lacks representatives of the mantle reference frame. Despite this problem, several features of the Neoproterzoic-Paleozoic geological and paleomagnetic records favor the possibility of multiple episodes of large and rapid TPW. One geodynamic precondition for polar instability is near-equivalence in magnitude of the planet's maximum and intermediate moments of inertia. A nonhydrostatic figure satisfying this condition is a prolate spheroid, which if stable over a long time could generate TPW along nearly the same great-circle. Vendian-Cambrian APW paths generally follow great-circles, consistent with this model. TPW as fast as 90 degrees in five million years is geodynamically possible; thus the present paleomagnetic database (with reliable poles typically separated by 10 Myr or more) is incapable of resolving the exact endpoints of possible Vendian TPW swings. Nonetheless, evidence from one well constrained continent, Laurentia, appears to support at least two round-trip polar excursions at rates as fast as 100 cm/yr. TPW is an attractive hypothesis for such rapid motion.

VARIATIONS OF THE EARTH'S ROTATION SPEED AND GEODYNAMICAL PROCESSES IN CENTRAL AND SOUTH ASIA

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Pairs of large earthquakes (M~7.0) are observed in Central and South Asia: a deep-focus Hindu Kush earthquake followed by a shallow event during an interval varying from a few weeks to 4,5 months. Distances between epicenters of these events are within a range of 300-1450 km. Strong shallow earthquakes after deep-focus Hindu Kush events have occured in the regions of Kopet Dag, Iran, Turanian plate, Hindu Kush, South Tien Shan and Himalaya. A probability of occasional occurence of 9 pairs of such earthquakes since a beginning of this century is insignificant. We have established, that these events occur only during episodes of long-term (few years) increase of the Earth's rotation speed. To interpret this effect we have considered temporal variations of shear wave attenuation field structure in the earth's crust and upper mantle, which are connected with an active fluids migration within large deep fault zones. For this purpose an unique experimental matherial has been analyzed - seismograms of local explosions at a small quarry in the region of the North Tien Shan, obtained in 1965-1995. Using coda analysis, we have shown, that during periods of increasing the Earth's rotation speed and especially after the strongest Hindu Kush earthquakes the fluid field comes to "exited" condition in the earth's crust and upper mantle, which stipulates a sharp acceleration of formation processes of large shallow earthquakes sources in most prepared areas. The data obtained point out that an information on preparing deep-focus Hindu Kush earthquakes is passed through active deep fault zones due to a perfect system of hydrodynamic ties.

APPARENT POLAR WANDER OF THE HOTSPOTS: THE VIEW FROM THE PACIFIC

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Paleomagnetic poles determined from the skewness of Pacific marine magnetic anomalies have compact confidence regions and precisely known ages. Our results include estimates of the skewness of 2,200 crossings of 23 distinct magnetic anomalies over seafloor ranging in age from 20 Ma (chron 6) to 81 Ma (chron 33r). The resulting path of apparent polar wander (APW) is based on many more data than the widely used path based mainly on seamount poles, paleolatitude data, and equatorial sediment facies. The new APW path differs from the old path in several important ways: (1) The path from skewness data is offset to the east from most of the old path. (2) The implied amount of northward motion of the Pacific plate since 75-81 Ma is substantially less from the skewness data than from the seamount poles. (3) Seamount poles and equatorial sediment facies indicate no shift of Pacific hotspots relative to the spin axis since 40 Ma, which is inconsistent with the well-documented significant shift of Atlantic and Indian hotspots. In contrast, the skewness data indicate a large and significant shift since 20 Ma. (4) The pole for 81 Ma from skewness data lies 30 degrees from a pole for 88 Ma determined from seamount magnetism; this large distance between poles so close in age may indicate an episode of rapid true polar wander from 88 Ma to 81 Ma, which may coincide with the end of the Cretaceous Normal Polarity Superchron. (5) Comparison of the APW of Pacific hotspots with that of Atlantic hotspots indicates some similarities and some differences: the latter may indicate motion between hotspots, errors in the reconstructions, or unmodeled errors in the paleomagnetic poles.

GLACIAL ISOSTATIC ADJUSTMENT AND THE EARTH'S ROTATION: NEW INSIGHTS INTO AN OLD PROBLEM

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We revisit the theory and predictions of glaciation-induced variations in the rotation rate of the Earth and true polar wander (TPW). The two most common theoretical formulations associated with TPW driven by the surface loading of a viscoelastic Earth [e.g., *Sabadini et al.*, 1982; *Wu and Peltier*, 1984] appear to diverge, and the differences have been the source of ongoing debate. We will show, using a generalized theory, that the two formalisms yield essentially equivalent predictions. We will then present two sets of forward predictions. The first set illustrates the sensitivity of TPW predictions to variations in mantle viscosity as well as assumptions regarding incompressibility and the treatment of the density discontinuity at 670 km depth (phase or chemical boundary?). The second set explores the feedback between rotation variations and a suite of widely discussed glaciation-induced observables. In particular, we explore to what extent past predictions of these observables, which assume a non-rotating planet, are modified by the action of a perturbing rotational potential.

EARTH ROTATION AND GLOBAL CHANGES

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The glacial eustatic rise in sea level after the 20 ka glaciation maximum led to an increase of the eqiatorial radius and hence caused a general deceleration. The sea level rise can be approximated by two superposed exponential curves with a transitional period some 13-10 Ka radiocarbon years BP. This period is known for high-amplitude climatic changes and regionally irregular changes in sea level. We interprete this as a breaking down in the continuos deceleration compensated by rapid redistributions of ocean water masses and related interchanges of angular momentum between the hydrosphere and the solid Earth. At about 6000 BP the glacial eustatic rise in sea level finished and a quite new situation began that is characterized by the interchange of angular momentum between the solid Earth and the hydrosphere (i.e. the main ocean circulations system). Because of the oceans high heat storing capacity, this redistribution of water masses (e.g. pulses in the Gulf Stream transport) generates climatic changes on a decadal-to-century basis (some sort of Super-ENSO events) that are of regional dimentions. This is testable by the available instrumental records of the last 300 years.

TRUE POLAR WANDER AS A MECHANISM FOR LONG TERM SEA LEVEL VARIATIONS

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Long-term, global scale, sea level variations are well documented. Analyses of data from North America and Europe suggest a second-order sea level cycle extending from at least the Cretaceous to the present day. The origin of this cycle, as well as its amplitude and geographic extent (global or regional?) remain controversial. It has been suggested [for example, by Morner, 1981] that long term sea level variations may be linked to changes in the Earth's rotation. This possibility is supported by the recent study of Sabadini, Doglioni, and Yuen [*Nature*, 1990], who showed that relatively rapid episodes of true polar wander ($\sim 1°$/Ma) may be an important controlling mechanism for third-order sea level cycles. We have extended the analysis of Sabadini et al. [1990] to consider sea level variations driven by much longer term true polar wander. Our calculations are gravitationally self-consistent and incorporate both the paleomagnetic record of true polar wander over the last 130 Ma as well as continental movements over this time. We conclude that long term sea level variations over the last 130 Ma are a combination of both global (that is eustatic) and 'quadrential' (true polar wander induced) signals.

TRUE POLAR WANDER AND HOT-SPOT MOTION DURING THE CENOZOIC FROM MANTLE FLOW MODELS

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The Earth's rotation axis is determined by the nonhydrostatic moments of inertia, which depend on the density distribution in the Earth; the density field, which evolves as convection and other dynamic processes in the mantle occur. Current models of the density distribution in the mantle, inferred from seismic tomography, have successfully accounted for the geoid. We use flow models driven by such internal density heterogeneities and by lithospheric plate motions to study the evolution of the density and flow fields in the mantle over the recent geological past. The models predict the evolution of the moments of inertia, and hence the rotation axis. They also predict the motion of hot-spots and thus relate the rotational, inertial, plate tectonic and hot-spot reference frames.

The models predict true polar wander that is in good agreement with paleomagnetic results for the past 60 My. The predicted current rate of polar motion from the models is about 30% of the observed rate and hence should be taken into account in models of polar motion based on post-glacial rebound. The current polar motion appears to be driven primarily by the evolution of subduction in the SW Pacific.

LONG TERM STABILITY OF EARTH'S ROTATION AXIS

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Paleomagnetic data show that Earth's rotation axis is remarkably stable, with less than 1000 km of net notion between the paleomagnetic and hotspot reference frames, or "true polar wander", (TPW) during the past 100 million years. This stability is surprising since Earth's inertia tensor is controlled by internal mass rearrangements on the same timescale resulting from mantle convection. Here we show that Earth's long-term rotational stability can be explained by the slow rate of change in the large-scale pattern of plate tectonic motions during Cenozoic and late-Mesozoic time, provided that subducted lithosphere is a major component of mantle density heterogeneity generated by convection. This explanation suggests that it is unnecessary to invoke other causes, such as sluggish readjustment of the rotational bulge, to explain the observed low rate of TPW. However, in other periods of Earth's history, the difficulty for the equatorial bulge to move may have controlled the Earth's rotation axis.

THE LONG-TERM ROTATION DYNAMICS OF THE EARTH

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The redistribution of mass at the surface or within the mantle is responsible for the readjustment of the Earth with respect to its axis of rotation, called true polar wander (TPW), on a wide range of time-scales: from 10^3 yr due to post-glacial rebound, to $10^7 - 10^9$ yr due to mantle convection. TPW can be deduced from paleomagnetic data, assuming that the average paleomagnetic axis coincides with the paleorotation one. When the long term rotational dynamics of the Earth is considered, changes in the moments of inertia due to mantle and surface loads and to the centrifugal deformation must be taken into account. These two contributions are sensitive to the density and viscosity stratification of the mantle, which implies that comparisons between dynamic model results and TPW data can be used to constrain the viscosity structure of the mantle. The slow, but resolvable rate of TPW since the early Tertiary of $0.1° - 0.2°$ per million years, has thus profound implication for the long-term rotational dynamics of the Earth and for the viscosity stratification of the mantle. We show the sensitivity of TPW paths, due to subduction zone reorganization and due to the continuous occurrence of ice ages, on density and viscosity stratification, for time scales characteristic for the readjustment of the equatorial bulge.

MAGNETIC FIELD OF THE EARTH AS A RESULT OF VARIATION OF ITS ROTATIONAL REGIME

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Now is generally accepted the conception of generation of geomagnetic field in the form of hydromagnetic dynamo, based upon the ideas about some hypothetical convection of substrance in the Earth's quasi-liquid nucleus. In the proposed model, as a source of energy to support the geomagnetic field, are taken the forces of interaction of the rotating Earth with the Galaxy's magnetic field.

The Earth as a magnet moving in a variable Galaxy's magnetic field has to suffer a certain moment of rotation. Along with it, in accodance with the laws of mecanics, its moment of momentum has to be constant. To satisfy these two requirements simultaneously is possible only provided that some turn-over of the internal nucleus in relation to the external one and the mantle takes place. It is evidenced by the displacements of the rotation's poles over the Earths surface. The movements of the facings of the double electrical layer appearing on the boundary of the inner and exterior nuclei generate the modern geomagnetic field. The initial stage of appearing of geomagnetic field in time is connected with the formation of the nucleus in the Earth that is capable to turn-over and as an initial magnetic moment of the iron-nickel nucleus could be taken the one caused by induction of the Galaxy's magnetic field. The proposed model gives the solution for one of the fundamental problems in the earth sciences. Its distinctive peculiarity is the above common mechanism of generating the geomagnetic field and deformation of the upper part of the Earth.

POLAR WANDER, SEA-LEVEL VARIATIONS AND ICE AGE CYCLES

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There exist close connections between changes in the Earth's rotation axis with respect to a deep mantle reference frame (True Polar Wander), variations in sea-level, the rise and decline of geological Ice Ages, and global change on geological time scales. The modeling of these interrelationships has received renewed attention in the last few years, after initial attempts to relate these phenomena in the '80s by means of solid earth relaxation models had shown its feasibility.
An overview is given of the models, and several aspects of the various interrelationships are discussed. It is shown that the viscosity profile of the solid earth has an important influence on these interactions.

THE RELATIONSHIP BETWEEN SOLAR WIND ENERGY AND 27-DAY NON-TIDAL VARIATIONS IN THE LENGTH OF DAY

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It is shown that solar rotation period-mean values of solar wind energy are closely related to an amplitude of 27-day non-tidal variations in the length of day: coefficients of correlation can reach values of $r \sim 0.8$ at a time lag of 15 to 20 days average. However, the mechanism of effects may be only of a kind of trigger since a solar wind torque and energy flux are 1 to 2 orders of magnitude smaller than necessary. Such a mechanism may be an increase in an atmospheric number density of CO_2 in the auroral oval due to a change in the atmospheric circulation from the meridianal type to the zonal one under enhanced particle precipitation heating [Bucha V. Ann. Geohphys (1988), 6, p. 513]. The authors have been supported by Science and Technology Center in Ukraine Grant 471.

CONTRIBUTIONS TO PRESENT-DAY POLAR MOTION, J_2 AND UT1 CHANGES

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The present-day secular polar motion is about 4mas/yr toward northern Canada obtained from 100 years of astrometric data. Recent estimates of secular change in Earth's oblateness find $dJ_2/dt = -2.7 \pm 0.4 \times 10^{-11}$/year from laser tracking of artificial satellites over the past 2 decades. The quadratic change with time of Earth rotation is 31.7 ± 0.5 sec$(T/Cy)^2$ and is obtained from 3 millennia of ancient lunar and solar eclipse data. The tidal contribution from laser tracking of moon and artifial satellites is well determined and the inferred nontidal contribution is $-10 \pm 1(T/Cy)^2$ sec. If interpreted in terms of changing rebound, the corresponding rate is $dJ_2/dt = -3.2 \pm 0.3 \times 10^{-11}$/year. This 20 Cy average should be larger than present-day rebound by a factor of $(1+6.7Cy/\tau)$ where $\tau \sim 40Cy$ is the rebound time scale. The fact that these 2 different estimates of oblateness change agree suggests that other sources either fortuitously cancel or are small. Until recently, post glacial rebound seemed to be the primary source for all three signatures. Contributions from ongoing melting of ice sheets, plate motion and by inference mantle convection were all estimated to be a factor of 5 or more smaller than the rebound signature. However, recent modeling of advected density anomalies suggest that mantle convection accounts for 1/3 of the present-day drift and is consistent with 20 My average from the paleomagnetic record. Constraints on mantle viscosity profiles imposed by dJ_2/dt and secular PM are weak partly because of this contribution and partly because of rebound PM sensitivity to isostatic support by the crust. I will discuss rebound models for polar motion, UT1 and dJ_2/dt and compare with model estimates of additional contributions and the observed signature. I will also discuss different mechanisms for long term drift.

SE8 Sedimentary basin modelling and integration of geophysical and sedimentary geology data

Convener: Cloetingh, S.
Co-Conveners: Horvath, F.; Sassi, W.

Sponsorship: Internal Lithosphere Program ILP

NEW SEISMIC DATA ALONG THE LATIUM-CAMPANIA OFFSHORE (EASTERN TYRRHENIAN MARGIN)

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Unlike the western Tyrrhenian margin, where relatively simple lithospheric stretching and mainly E-W, ESE-WNW extension had occurred since post-Tortonian times, the eastern Tyrrhenian margin (ETM) experienced a rather complex deformational history since it was located on the back side of the migrating Apenninic accretionary wedge. Unpublished multichannel and single-channel seismics, coupled to well data, reveal unexpected tectonic and sedimentary features along the Latium-Campania offshore in correspondence to the Terracina-Gaeta, Napoli and Salerno basins. In these basins the Meso-Cenozoic tectonic units of the acoustic basement are downthrown by listric normal faults and generate N-S to ENE-WSW trending half-grabens. Plio-Pleistocene sedimentary fill in the basins, exceeds, at places, some 3000 m and is made up of clastic marine, coastal and deltaic sediments intercalated with lavas and pyroclastic deposits related to widespread volcanism. In the Napoli and Salerno basins bathymetry and high resolution seismics shows the occurrence of partly fault-controlled canyons (i.e. Dohrn and Magnaghi canyons) which engrave the continental shelf up to near the shore and join, seaward, the Capri-Salerno E-W canyon. Wedging geometries, tectonic unconformities and occurrence of hummocky reflectors and chaotic facies at various stratigraphic levels are hints of synsedimentary tectonics and strong uplift of the mainland during Pleistocene.

The Early Layer Parallel Shortening (LPS) as Revealed by Magnetic Fabric.

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The purpose of this talk is to present a quick mean to describe the early stage of the LPS in apparently undeformed sedimentary rocks.

Magnetic fabric determination is fast (less than 5 mn/sample), accurate (anisotropy of 0.1%) and volumetric (10 cc). In addition, magnetic fabric can measured on a wide variety of rock types.There are typically two suitable materials to reveal the LPS in the early stage of its development.

1) Marls exhibit a magnetic lineation within the bedding at ***a right angle*** of the LPS direction. This magnetic lineation is quite hard and resists generally to further deformation. It behaves therefore as passive marker.

2) Sandstones give the most spectacular results because they show a developement of magnetic foliation ***perpendicular*** to the bedding. This magnetic foliation has generally no expression on the field, neither in thin section. We will present a positive fold test which clearly show a pre-tilting acquisition of the magnetic fabric

These results indicate that an ***internal deformation*** accompanied the LPS. This has important consequences for modelling the deformation of a sedimentary cover. We will present a model of the development of the LPS which suggests a ***forward propagation*** of the internal deformation. An example from a record of an early LPS in the Akseki Arc (Taurus, Turkey) will support our view.

TECTONIC MODELLING OF THE LATE CENOZOIC THICK-SKINNED CRUSTAL DEFORMATION IN CENTRAL ASIA

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Topographic and gravity data show that large-scale topographic undulations in Central Asia occur at surprisingly constant wavelength. Three dominant wavelengths (5-10 km, 50-60 km and 350 km) superimposed on each other can be distinguished. The long-wavelength folding north of the Himalayan collision belt is similar to folding of oceanic lithosphere in the Indian Ocean south of the Himalayas. This symmetry suggests a common origin, namely regionally high compressional intraplate stress induced by the collision of the Indo-Australian with the Eurasian plate. We present results of two-dimensional finite element models of the mechanical response of continental lithosphere with a complex multi-layered rheology and subjected to compressive loading. The observed first-order undulations are reproduced only by plate models with a thermal age of less than 100 Ma. This is in agreement with geological data suggesting Cenozoic thermal rejuvenation of Central Asia. The second order undulations most likely reflect the folding of the crust which is decoupled from the underlying subcrustal lithosphere. Third order undulations are caused probably by folding of the mechanically strong upper crust. The thermally rejuvenated lithosphere of Central Asia is mechanically weaker than the surrounding areas, because of the strong influence of the increased temperature on the yield strength. Our models suggest that this thermal weakening may explain why the Cenozoic crustal deformation occurs only in Central Asia.

CENOZOIC STRUCTURAL EVOLUTION OF THE PANNONIAN BASIN: PALEOSTRESS DATA AND FINITE ELEMENT STRESS MODELS

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Using all available paleostress data, seven main structural events are separated in the Pannonian basin and surrounding Alpine belts that are delicately reflected in the evolution of the paleostress fields. The combined analysis of stress indicators and the results of finite element stress modelling have shown that the state of stress in this region was governed by distinct tectonic factors. A strong correlation exists between the observed stress pattern and the boundary conditions effecting the area. Of key importance is the relatively continuos northward drift of the Adriatic microplate with respect to Europe. As a result, active shortening at the South Alpine - Dinaric front played an important role in the stress evolution throughout Cenozoic times. The formation and evolution of the Pannonian basin system was mainly controlled by two additional processes during Neogene through Quaternary times. First, subduction of the European plate beneath the internal (i.e. ALCAPA and Tisza-Dacia) units resulted in a slab pull force at the outer Carpathian front which may account for both tension (stress) and extension (strain) observed in the Pannonian basin. Second, body forces arising from density contrasts induced by the overthickened orogenic crust in the Eastern Alps and the presence of an asthenospheric dome beneath the basin centre could have also significantly influenced the reconstructed stress pattern.

FAULTING, FRACTURING AND IN-SITU STRESS PREDICTION IN HYDROCARBON RESERVOIRS: A FINITE ELEMENT APPROACH

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The finite element method is used to compute in-situ stresses and rock deformation in a hydrocarbon bearing fault-propagation-fold structure, and to predict reservoir fracturing as a function of material properties, structural position and tectonic stress. Two-dimensional plane-strain end-member models show that the presence of a thick shale layer leads to a mechanical decoupling of the structural deformation of the shallower sediments from the underlying sediments and basement. All models predict rock fracturing to initiate at the surface and to expand with depth under increasing horizontal tectonic compression. The stress regime for the formation of new fractures changes from compressional to shear with depth. If pre-existing fractures exist, only (sub)horizontal fractures are predicted to open, thus defining the principal orientation of effective reservoir permeability. In models which do not include a blind thrust fault in the basement, flexural amplification of the initial fold structure generates additional fracturing in the crest of the anticline. The folding-induced fracturing expands laterally along the stratigraphic boundaries under enhanced tectonic loading. Models incorporating a blind thrust fault correctly predict the formation of secondary syn- and anti-thetic mesoscale faults in the basement and sediments of the hanging wall. The faults divide the structure in compartments with different levels of stress and rock failure. Some faults cut reservoir and seal layers, and thus may affect seal integrity and influence effective reservoir permeability.

STRUCTURAL - FORMATIONAL MODELLING OF SEDIMENTARY BASINS

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The methodology of the structural-formational interpretation (SFI) for the earth crust and upper mantle study of sedimentary basins is based on the three interaction methodical technologies: structural-formational analysis, seismic modelling and geological processes modelling. SFI operates by the quantative seismogeological earth crust models and possesses powerful means of automatic processing. Spectral-time analysis and range structural-formational approach in investigations of crust-mantle and sedimentary formations characterize the inner structure and genetic interrelations between structural - deformative bodies crust and sedimentary cover. Modelling on base SFI includes: logical hierarchic dismemberment earth crust of the sedimentary basin on the seismoformational and tectonomagmatic complexes, seismoformations and crust-mantle heterogeneties; tectonoformational complexes and depth fault zones of different age correlation; paleotectonic and paleogeographic seismofacial analysis; geological processes modelling and seismogeologic model of lithosphere sedimentary basin construction. SFI successfully use for interpretation of the materials regional depth investigations by the method of converted waves from earthquakes - deep seismic sounding (MWCE-DSS) and CDP in complex with well-logging data in different oil-gas - and ore-bearing regions in Russia.

LATERAL DIAPIRIC EMPLACEMENT OF TRIASSIC EVAPORITES AT THE SOUTHERN MARGIN OF THE GUADALQUIVIR BASIN, SPAIN

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The Guadalquivir Basin is the Neogene foreland basin of the Central and Western Betic thrust belt in southern Spain. At the boundary between the basin and the outcropping thrust nappes of Mesozoic limestones is a broad belt of outcrops of Triassic evaporitic sediments with scattered younger rocks - the so-called 'Olistostrome' unit. This is highly deformed and its mode of emplacement has been traditionally attributed to olistostromal debris flow, diapirism, or tectonic melange. Studies of outcrop data in conjunction with seismic and well data, integrated using restorable cross-sections lead us to propose the following sequence of emplacement mechanisms: a) Loading above a Triassic evaporite formation by north vergent thrusting of thick nappes of Mesozoic sediments, causes northward expulsion of evaporitic sediments; b) continued thrust loading drives the diapiric body forwards ahead of the thrust belt, into the floor of the deepening Miocene foreland basin; c) when the diapiric body reaches the sea-floor of the basin, its top becomes subject to modification by sedimentary processes such as dissolution of evaporites leaving a cap rock and debris flow, both submarine and subaerial but rarely, if ever, forming true olistostrome; and d) at the leading edge of the diapir, northward compression of Miocene basin sediments results in thin-skinned thrusting within these sediments, and formation of duplex structures with a north-dipping monoclinal deformation front. Results from analog and numerical modelling match the main geological features observed in the study area, thus supporting the plausibility of the proposed lateral diapiric emplacement of the chaotic body.

THERMOCONVECTIVE INSTABILITY OF THE LITHOSPHERE AND SEDIMENTARY BASINS FORMATION

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The thermoconvective stability of the continental lithosphere is analysed. The lithosphere is modelled as a horizontal layer heated from below. For small strains the rheology is described by the linear integral law which reduces to the Andrade law for transient creep in the case of constant stress. The upper boundary of the layer is considered as an isothermal deformable surface loaded by sediments the thickness of which is changed with time. Sedimentation and erosion are described by the diffusion equation where the erosional transport coefficient is much less than the depositional coefficient. Solving the stability problem we find the dependence of sediments thickness on time which is consistent with the observed age-depth relation for sediments from the Williston Basin.

EROSIONAL FORCING ON THE BASIN ENVOLUTION

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Most basins are characterized by very important quantities of the sediments (5 to 20 km). Corresponding volumes of the material are comparable with the local changes in the volume of the crust submitted to extension/subsidence. It is logical to assume that the way in which the material is being deposited and eroded is as important as the way in which it is being deformed tectonically. Thus a kind of feedback should exist between the mechanical evolution of the basin and surface process. We conducted numerical simulations of simultaneous extension, erosion and subsidence. Our results show that the surface processes can significantly change the rate and style of extension and subsidence of the basin and evolution of its shoulders. For example, under the same boundary and initial conditions, intensive erosion/sedimentation during the rifting "creates" a much larger basin, with almost 2 times greater "***apparent***" coefficient of extension. This can obviously change existing interpretations of the style of extension and estimates of the rate of the post-rifting subsidence derived from the conventional models. The other obvious result is that the surface processes greatly influence the geometry and evolution of the rift shoulders, and distribution and evolution of the faults .

COMPARISON AND INTEGRATION OF GEOPHYSICAL AND SEDIMENTOLOGICAL DATA FOR BASIN MODELING

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Shallow sedimentary basins developed on the North American craton are ideal to experiment with the comparison and integration of earth-science data. Many basins have been explored for hydrocarbons and multitudes of reliable data are available. A comparison/integration technique was developed for a quick first approach to obtain basic information on the formation and development of a sedimentary basin. The technique requires the gridding and standardization of spatial data to use for a pairwise comparison of each dataset, graphically represented by a dendrogram, and a stacking of datasets to compute an integrated resultant map. Results of the integration are: (1) a spatial representation of the areas of similarities and dissimilarities and (2) a correlation coefficient giving the overall similarity expressed as a percent. This approach has been used to determine the relationship between variables and which variable or combination can predict other variable(s) in the Cherokee Basin (Kansas, USA).

TECTONIC AND CLIMATIC INFLUENCES ON LATE CENOZOIC MOUNTAIN BUILDING AND BASIN FORMATION IN EAST-CENTRAL ASIA

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The Late Cenozoic in the Tian-Shan, Altai, Sayan and Baikal regions of Central Asia is a period of synchronous active mountain range and sedimentary basins formation. Three independent factors control the crustal and topographic evolution: upper mantle processes, far field stresses and climate change. The simultaneous tectonic intensification over a wide area in Central Asia in Late Pliocene - Early Pleistocene suggests a plate-scale phenomenon. However, this seems unrelated to plate boundary forces, since no significant changes are evident in plate boundary kinematics and convergence rate around 3 Ma. An alternative cause might be located in the Asian plate itself. A possible candidate is the delamination of Tibet which can generate compressive forces north of the Tibet Plateau, in the same order of magnitude as far-field tectonic forces. The apparent increasing of mountain ranges uplift rate in the Middle-Late Pleistocene is even a more global event, since this has been observed worldwide. Global climate cooling could be such an event. By intensification of erosion, it accelerated the material transfer from the mountain ranges to the sedimentary basins and the isostatic compensation will cause additional relative uplift of the mountain ranges and subsidence of the basins, triggering the system.

Gravity anomalies used in 3D-basin analysis of the Dutch on- and offshore.

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The different densities of the sub-cropping rock units within a basin significantly affect the observed Bouguer anomaly. This study aims to construct a 3D gravity model of the Dutch on- and offshore, with respect to subsurface density variations and will contribute to a deeper understanding of the subsidence history of this region. The problem is approached by digitising key horizons (base Tertiary, base Cretaceous, base Permian, top basement and Moho). The gravity effect of the basin model is then derived using either a linear- or exponential density depth function for the region of the horizon interval map and subtracted from the total field. The residual field is derived from deeper sources including Moho topography and anomalous densities in the sedimentary succession. Providing constraints on compaction trends in the Dutch on- and offshore, the gravity modelling enhances evaluation of maximum burial depth, quantification of erosion magnitudes, periods of non-sedimentation and original thickness and composition of eroded rocks. Coupled studies using various data sets, like seismic- and well log interpretation as well as vitrinite reflectance and fission track analysis will enable the construction of detailed 4D models of the subsidence history of the Dutch on- and offshore. This technique will significantly improve the knowledge of chronological and lateral constraints for basin evolution.

NORTHERN FORE-CAUCASUS MOLASSE BASIN: BURIAL HISTORY AND FLEXURAL MODELLING

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Fore-Caucasus basin was originated in Triassic time as a rift basin and later has suffered several episodes of extension and compression. We focus mainly on the Late Cenozoic collisional history of the basin which started in Oligocene by a broad subsidence caused probably by deep processes in upper mantle. From Middle Miocene the Great Caucasus orogen and foredeep basins were formed. We present the results of flexural and gravity modelling for different parts of the Caucasus and its foreland. The formation of molasse basin is correlated with orogenesis of Great Caucasus mountain but the topographical loading itself is not sufficient to induce observed subsidence and does not explain observed in-plane basin configuration. The deepest areas of foreland basin are on the tips of orogen where mountain heights are negligible and Central Caucasus area adjacent to the highest mountain is uplifted now. To produce good fit with the gravity and basin architecture we put additional controls into the model: subsurface loading, crustal and lithospheric thickening, removal of lithospheric roots and bending momentum. This allows us to obtain good fit in the Central and Eastern Caucasus, but for the orogen edges the fit is not good enough and this problem required further development. Found EET values are near 50-60 km for eastern and 10-20 km for western parts.

GEODYNAMIC FINITE-ELEMENT-MODELING OF FORELAND BASINS

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In the Late Carboniferous (Pennsylvanian) the Variscian foreland of Western Europe was formed north of the Variscian deformation front and extended 800 km parallel to the Variscian front. A newly developed high resolution time-scale based on sedimentary records of the Late Carboniferous in the Ruhr Basin makes quantitative basin analysis in broad areas of the North Sea Basin possible. The results suggest different dynamic scenarios simulated by finite element investigations.
Finite element studies allow to combine geological and geophysical knowledge with the physical behavior of the lithosphere to study the development of foreland basins. In a first step different 3-dimensional models are compared to the evaluated subsidence of the Variscian foreland. The second step takes erosional and sedimentary processes into account to investigate their influence on the subsidence and the tectonic development of the foreland. The boundary conditions of the FE-models are crucial for the development of the models and for the results. Therefore, these boundary conditions have to be studied very carefully in order to archive results only depending on the physical properties of the rock and the geological structure.

NUMERICAL MODELING OF THE EVOLUTION OF THE GUADALQUIVIR FORELAND BASIN (SOUTH SPAIN).

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2D and 3D numerical modeling has been applied in the Betics-Guadalquivir region to relate the geometry of the basin sediments with the emplacement of the Betic thrust sheets and with the mechanical behavior of the Iberian lithosphere. The numerical models include non-instantaneous loading (lateral thrust emplacement), surface processes (erosion and sedimentation), and the mechanical behavior of the lithosphere (thin plate and rheological models). The results show that a thin plate elastic model can fit the basement deflection when a hidden subcrustal load, in addition to topographic and paleobathymetric loads, is considered. On the basis of geoid and gravity observations, we interpret the hidden load as the consequence of lithospheric thickening under the basin and the Betics. To explain the basin infill geometry, it is necessary to apply either a multilayered rheology or a viscous relaxation after the load emplacement or a combination of both models. Extensional faults observed in the basement, which occur during the beginning of the basin formation, are explained by using a flexural model with multilayered rheology.

THE DEEP STRUCTURE OF THE DEAD SEA

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In order to get a good estimate of the depth to basement in the Dead Sea a seismic refraction experiment involving the use of 9 OBS and 11 portable seismic land stations was conducted along a north-south profile in the north basin of the Dead Sea. The velocities obtained from the seismograms were: 2.0 km/s representing the Pleistocene sediments followed by a 4.2 km/s layer which is present at some OBS location and represents evaporites. This layer is in turn followed by a 3.0 km/s layer which represents pre-Pliocene sediments. The crystalline crust is represented by a 6.0 km/s velocity layer. The interpretation of the recorded seismogarams indicates the presence of two large Pliocene salt diapirs in the young basin fill. The basement lies at a relatively shallow depth (5-6 km) under the north basin. Further south along the profile a major fault was detected. This major faulting with a downthrow of some 4-5 km has depressed the crystalline basement and the overlying Cretaceous and pre-Cretaceous sediments in the southern basin of the Dead Sea. The faulting was followed by the deposition of over 8 km of Recent and Tertiary sediments resulting in a 14 km thick sedimentary sequence in the south basin of the Dead Sea. Partial Moho reflections indicate that the crust is 27-30 km thick. The seismic data and the model for the deep structure of the Dead Sea are presented.

PRESENT-DAY STRAIN AT THE MID-NORWEGIAN MARGIN

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Predictions on present-day lithosphere strength across the Vøring Margin are incorporated in two dimensional finite element models. The modelling aims to analyse deformation patterns and to describe implications of lateral lithosphere strength variations on the stress field within the Cretaceous-Cenozoic sediments. The modelling results indicate localisation of horizontal and vertical strain at Moho depth beneath the Helland Hansen Arch. Strain localisation at depth is accompanied with doming of the surface. Despite the mechanical decoupling of sedimentary cover and upper crust from sub-crustal domains, sub-crustal mechanical properties influence the surface topography. The results suggests that for an estimated lithosphere strength configuration, surface topography differs in magnitude only with respect to changes in the far-field stress. In contrast, modifications of lithosphere strength results in an altered surface geometry. Within the sediments stresses are deflected at the basin margin. At the location of the Helland Hansen Arch stresses concentrate at depths of about 4 km. The predicted high stresses at this depth may induce overpressure, which would represent a likely explanation for the observed poor seismic resolution.

BOTHNIAN SEA -A MESOPROTEROZOIC EXTENSIONAL BASIN

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The Bothnian Sea is located on the Fennoscandian Shield between Southern Finland and Central Sweden. The Paleoproterozoic Svecofennian bedrock is covered by Mesoproterozoic Jotnian sandstone and younger Cambrian and Ordovician sediments. The Bothnian Sea sedimentary basin is composed of several inter-connected basins which are partly exposed on land. The new marine gravity data together with the deep reflection and refraction data of the BABEL-experiment are used as data for our interpretation of the origin of the sedimentary basins.
In the south the basin is a thin-skin basin developed on top of listric shear zones that can be traced to the sea bottom. The continuation of the Satakunta sandstone graben is seen as a V-shaped, high-angle normal fault bounded graben filled with granitic material. The normal faults which are at cross angles with the listric shear zone are interpreted as transfer faults. The north-eastern part of the basin comprises of a 3-4 km deep sedimentary basin on top of rapakivi granite laccolith. The sedimentary basin as well as the underlying granite are intruded by highly reflective dolerite sills. The lower crust underneath is highly reflective and concave upwards. Listric reflectors flatten out in this layer as well. Underneath a new flat Moho has developed. The sedimentary basin is interpreted as a thermal subsidence basin that resulted from cooling of the extended lithosphere and underlying granite. The crustal structure resembles closely Coward's model for heterogeneous streching of the lithosphere.

3D SEISMIC REFRACTION TOMOGRAPHY OF OCEAN BOTTOM HYDROPHONE DATA RECORDED OFFSHORE VALPARAISO, CHILE

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Offshore Chile (32° - 33° S), the Juan Fernandez aseismic ridge subducts into the Chile Trench at a rate of approximately 100 mm/y. The Valparaiso forearc basin lies opposite the subducting ridge at a midslope depth, one of only a few significant basins along the central Chilean margin. The study region is also a site of large historical earthquakes and enhanced shallow seismicity relative to areas north and south along the margin.

To investigate the influence of seamount subduction on the margin structure and its relationship to the local seismicity pattern, seismic wide-angle data were collected during the cruise of RV SONNE 103 in 1995. Both in-line (2D) and off-line (3D) data were acquired with ocean bottom hydrophones using a star-shaped network of 10 intersecting lines. The resulting data constrain the crustal velocity structure in 3D over a 85x85 km region to ~20 km depth, including the Valparaiso Basin, the frontal collision zone, the continental upper crust, and the top of the subducting oceanic plate.

This presentation will show results of a first arrival traveltime inversion using a fully 3D tomographic method incorporating regularization. Hydrosweep swathmapping and coincident deep and high-resolution seismic reflection data were taken into account to develop a true 3D inversion starting model and constrain the results.

APPLICATION OF THE GEOPHYSICAL DATA FOR SEDIMENTARY BASIN INVESTIGATION.

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Application of the geophysical data for investigation of the sedimentary basins allows to determine some important features of the structure and development of these interesting geologic phenomenas. Thus, the analysis of the structure and composition of the consolidated crust of the sedimentary basins within Euroasia shows that its thickness and composition are greytly varied in West, Central and East parts of the continent and depend on the geotectonic environment, where sedimentary basins formed. The reduced suboceanic consolidated crust is characteristic for sedimentary basins located in the West and East Euroasia, where destructive processes are widespread. On the contrary, in the Central part of the continent, where the constructive pocesses of the increasing of the Earth's crust take place, the thickness of the consolidated crust within sedimentaty basins is comparable with it in the neighbouring orogenic and platform areas. Crust composition in these basins is more complicated: there are several layers with high and low velocities. The seismostratigraphic analysis of the sedimentary covers supplies the rich additional information on peculiarities of basin's developent The large sedimentical cycles may be detected, connected to certain tectonic stages of the whole geotectonic region. Besides, some subtle peculiarities of the sedimentary covers may be used for clarification of the sedimentary process.

THE DEVONIAN TO PERMIAN SUBSIDENCE MECHANISMS OF THE EAST EUROPEAN BASINS

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The mechanisms of basin evolution are examined to explain the rapid subsidence of the basins since the Devonian. Models of these mechanisms are compared with seismic, gravity, heat flow, and Devonian magmatism observations from the Timan-Pechora, Dnieper-Donets, Pre-Caspian, Moscow basins, and Pre-Uralian depression. The models assume that the development of the basins has been affected by one or more of the following processes: stretching of the lithosphere and thermal decay, mineralogical phase transition in the crust, magmatism and eclogitization-induced mantle flow in the uppermost mantle, subduction under the platform, and continental collision. While some features of basin evolution are in good agreement with one of the mechanisms, no specific model can explain all features of the platform basins. Non-uniform stretching and magmatism-eclogitization mechanism may explain the Devonian subsidence of the Dnieper-Donets, Timan-Pechora, and Pre-Caspian basins. The thermal decay and subduction-induced mantle flow is likely to be responsible for the Devonian to Permian subsidence of the Moscow basin, whereas the continental collision greatly affected on the evolution of the Pre-Uralian depression.

IDENTIFICATION OF SEDIMENT DISPERSAL PATHWAYS USING 3D PALINSPASTIC RECONSTRUCTION.

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In areas of structural complexity, the current location of sediment migration pathways and the extent of facies belts may be difficult to determine as their current dip and structural configuration may be different to that at the time of deposition.

Three-dimensional structural modeling allows horizons to be 'reconstructed' into their pre-deformation configuration by sequentially removing each horizon using a combination of 3D kinematic algorithms and decompaction. The kinematic algorithms model the deformation of horizons as they are moved over fault planes, maintaining the rock volume in the model to achieve a pre-deformation morphology. Three-dimensional decompaction allows the effects of differential sediment compaction to be modelled for each horizon.

At each stage of reconstruction a palinspastic topographic map of the surface at its time of deposition is generated and highlights locations where basins may be underfilled, or where a regional dip is present. Sediment dispersal pathways can then be mapped onto these horizons to determine the main sediment transfer fairways. This is achieved using a geometrical algorithm to create down-dip paths, using the maximum angle on each facet of the model, effectively mapping the pattern of sediment flow around topographic features identifying sediment traps and fairways.

This technique gives far greater control to sedimentary facies modelling, especially in areas where data is obtained from isolated well information, and hence greatly reduces risk where the reservoir quality is controlled by facies variations.

BÜYÜK MENDERES MULTIPARTITE GRABEN

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In the southern parts of central western Anatolia, the initial E-W striking Büyük Menderes graben formed on axial culmination of an antiform uplift by the late Middle Miocene. The graben superimposed onto the older Late Oligocene to Early Miocene NE-trending faults, early Middle Miocene N-S faults, and related sedimentary infillings and lineaments. During the late Miocene or early Pliocene times the western part of the initial graben underwent differential vertical movement (down in the east) across an older NE-trending deep fracture. Within the context of regional half graben tectonics commenced by the late Pliocene, the reactivation of the northern boundary fault gave rise to a medial uplift of the basement and a narrow satellite half graben to the north, in the western part of the graben. In both the initial southern basin and the northern satellite basin the basement has attained a southward tilting. To the east, the satellite graben and the medial uplift were gradually replaced by the steeply southward dipping fault sets of the initial northern boundary. Probably, this was accompanied by northward tilting of the basement in the initial graben, at least in places. During the Quaternary times, the general and progressive southward tilting of the basement to the north of the multipartite Büyük Menderes graben has led to the reactivation of the older low-angle shear planes and consequently present-day faulted boundaries of the onlapping graben infilling. According to gravity data, the sedimentary infilling of the multipartite graben has a thickness in the range of 2.5 km

The quantitative estimation of geological characteristics of sedementary basics by geothermal parametres

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The quantitative estimation of horizontal temperature gradients and the rate of their change with depth in the upper layers of sedimentary thickness is made on the basic of the statistical analysis of the results of long-standing boreholes, located within the limits of Dnieper-Donetz and Pripyat depressions. It has been established experimentally and theoretically that the view of function Ghor=f(H) depends on the relationship of conductive and convective components of heat flow. In the first approximation exponential dependancy Ghor=f(H) is due to prevalent influense of conductive component of heat flow and the logorithmic dependency - convective component. The connection of the geothermal field with the tectonic regime made it possible to introduce the quantitative estimation of the coefficient of nonstability of geological structures and to show its natural increase from the regions of ancient consolidation to young structures of increase geothermal activity.

MODELLING OF THE BARENTS SEA NEOTECTONICS.

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Barents Sea is situated to the north from the East- European Craton and to the west from Novaya Zemlya. Central part of the basin is located on the oceanic crust, originated in the Late Devonian . Basin filled by Paleozoic and Mesozoic sediments with thickness up to 18 km, the age of sediments is from late Devonian till Late Cretaceous. Sediments of Late Cretaceous and Paleogene are removed by erosion on the most part of the Barents Sea Region. The estimated volume of the eroded part is from 1.5 km till 5-7 km. The analyses of neotectonic movement of this region shows uplift of the Novaya Zemlya on 1000 m and subsidence of the central part of the region on 500 m. On the base of seismic and gravity data thickness of the earth crust in the region is vary from 40 km to 20-25 km. The thickness of the upper crust decrease from 15 km till 0 km. So, thickness of the lower crust in the central part of the basin is 12-15 km. Wide positive anomalies in gravity field is situated on the East - Barents Sea basin. In the north-eastern part of the Novaya Zemlya the manifestation of the Cenozoic volcanism (10 Ma) are found (volcanic pipes with basic and ultra-basic lavas). Analysis of the neotectonic map shows that maximal uplifts 200-1000 m correspond with shields and orogens around Barents Sea (Baltic Shield and Novaya Zemlya), and maximal subsidence (-350 m) movement are in marginal graben and East-Barents Sea depression. Proposed time of the movement is Pliocene - Quaternary.

3 profiles across East- Barents Sea basin and Novaya Zemlya were modelled. We suggest that neotectonic movements were caused by intraplate compression accompanied by Novaya Zemlya orogen loading. These two factors , superimpose on the lithosphere heterogenityes and induce flexural bending with pattern similar to the neotectonic movement. For the homogenous lithosphere the force inducing elastic buckling is too high. But the presence of the pre-deformational syncline-like lithosphere structure reduces force necessary to induce vertical subsidence. We have received results of the modelling close to natural profiles of the neotectonic movements.

Problems of salt dynamics for 3D-backstripping

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Salt layers often play an important role in subsidence history of sedimentary basins and for the exploration of mineral and energy resources. Because of its specific physical parameters and unusual behaviour in deformation processes, it causes a wide variety of geological structures. Constrained backward modelling of salt containing sedimentary basins, using 3D-modelling programs based on FE methods, helps to understand salt movement and analyse complex processes of interaction between salt and its environment.

In our study we use a 3D structural model of the Northeast German Basin as a starting point for backward modelling. In a process of backstripping we try to combine calculation of pressure, deformation and isostatic balancing. To simplify this model we assume that salt behaves like a viscose medium with hydrostatic balance and a constant volume in a long time run. For each step in backstripping the isostatic balancing of all layers is now combined with a 3D smoothing of salt structures, driven by the change of pressure, due to reconfiguration of its cover layers.

URL: http://www.gfz-potsdam.de/pb3/pb34/people/geochris.html

MULTI-STAGE TRANSTENSIONAL EVENTS AND SEDIMENTARY RESPONSES IN THE EASTERN TYRRHENIAN MARGIN (ITALY)

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The Eastern Tyrrhenian, and in particular the Gulf of Naples, features lithospheric thinning and Quaternary volcanism. The tectono-stratigraphic analysis of the peri-Tyrrhenian Gulf of Naples basin was reconstructed by means of 3500 km of seismic reflection data, plus structural data of the basin flank. Transtensional tectonics produced marked asymmetry in both structural styles and basin architecture. Indeed, we recognize three stages in the basin evolution: (1) formation of an half-graben basin filled by a Transgressive-Regressive cycle (Middle Pleistocene); (2) asymmetric subsidence producing accommodation space filled by a wedge of Late Quaternary pyroclastic deposits (42-25 ky B.P); (3) complex faulting controlling depositional and erosional processes on the shelf in the last 25 ky. The multi-stage Gulf of Naples basin evolution is, finally, linked to the activity of an E-trending left regional shear zone.

Modelling of salt dynamics in the Northeast German Basin

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This poster outlines the idea how we try to handle layers of salt in sedimentary basins for the process of 3D backstripping with FE-programs. It shows the problems in handling salt flow for backstripping processes as well as its influence for computation of paleo topography.

A 3D structural model of the present Northeast German Basin is taken as a starting point for backward modelling. To simplify its poorly constrained deformation kinematics we assume that salt behaves like a viscose medium with hydrostatic balance. A Combination of pressure, deformation and isostatic balancing calculations leads to results which takes the presence of salt into account.

Comparing results based on different approaches of salt movement as well as variation in the underlying crustal structures shows the influence of these parameters for further calculation and therefore for the evolution of this sedimentary basin.

URL: http://www.gfz-potsdam.de/pb3/pb34/people/geochris.html

REGIONAL GRAVITY AND AEROMAGNETIC INVESTIGATION OF THE TAKUTU BASIN, BRAZIL AND GUYANA

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The Takutu basin is an intracratonic rift valley forming an elongated structure oriented NE-SW, about 30 to 50 km wide and 300 km long, extending across the borders between Brazil and Guyana and developed during the Mesozoic, probably related to the opening of the equatorial Atlantic. The depression is the site of low magnetic relief and negative gravity anomalies, interpreted as being due to the sedimentary infilling. We have undertaken a regional gravity survey over the Takutu Basin, with the objective to evaluate the tectonic framework of the basin and surrounding cratonic region and to gain a better insight of the areal extent and depth to basement. The only existing gravity data available, prior to this work, was part of a country-wide acquisition project forming a long N-S profile in Brazil and a reconnaissance survey conducted in the early 1980's in Guyana, along with a seismic operation. The Bouguer anomaly map shows the regional structural trends and the approximate position of the basin boundaries. The digital aeromagnetic dataset used was in the form of a 1km data grid . A smaller window was selected , over the basin, to be processed with the Euler Deconvolution Method. The method enhanced features with a NE-SW trend and confirmed the location of known geological structures, giving estimations of their depths.

FLEXURAL MODEL OF THE SILURIAN BALTIC BASIN ON THE WESTERN MARGIN OF THE EAST EUROPEAN CRATON

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The sedimentary record of the Baltic Basin reveals a marked increase of subsidence rate beginning in the Late Ordovician, accelerating throughout the Silurian. Backstripping analysis indicates that tectonic subsidence rates increase towards the SW margin of the basin, adjacent to the Caledonian Deformation Front (CDF), where they reach values exceeding 100 m/My. The Silurian succession there could be thicker than 3-4 km. At a distance of 600 km from the CDF, it constitutes some 500 m of marginal facies carbonates. Lithofacies distribution indicates deepening of the basin to the west. Thus, the basin has the general characteristics of a foreland basin related to continental convergence processes occurring in the Caledonian Orogen. However, specific features of the basin architecture, including variations in its width and facies development, are not obviously explicable by a model of simple foreland flexure. Here, the flexure hypothesis is quantitatively tested using a 3D modelling technique that allows a complex distribution of loads and spatial variations of lithospheric strength. The results are interpreted in terms of their implications for the rheology of the EEC and the geometry and temporal evolution of Caledonian foreland loading compared to independent constraints for these.

2D AND 3D MODELLING OF THE THERMAL EVOLUTION OF SEDIMENTARY BASINS AND THEIR APPLICATIONS

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The study of the thermal effects due to sedimentation provides information regarding the thermal state of the sediments and the heat flux coming from the basement. The latter is relevant in terms of geodynamical interpretations. In this work we present a thermal model for a sudden sedimentation in 2D and 3D; this model can be extended to the case of sedimentation approximated by a series of episodes. The boundary effects determine a faster thermal evolution of the sediments than the one obtained for a boundless basin. However, this evolution is ruled by the physical and geometrical parameters of the basin itself. In addition, we show some applications referred to real sedimentary basins.

NEOGENE BASEMENT FAULTING AND SUBSEQUENT KARSTIC REJUVENATION:THE OIL-BEARING ZALA BASIN, SW HUNGARY

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The Zala basin in Western Pannonian basin is an example to demonstrate the importance of pre-rift phase geology in controlling the subsequent basin evolution and hydrocarbon prospects. The major part of the oil is stored in the karstified Mesozoic basement. Good reservoir properties are due to (1) a multi-phase meteoric karstic development during the Paleogene, before basin formation (2) deep burial hydrothermal processes during the Neogene when the karstified Mesozoic rocks subsided, and hydrothermal fluids enhanced the pre-existing karstic conduits.
The Neogene basin formation is a result of extensional and wrench faulting during the Late Paleogene and Miocene. Tertiary faulting created structural traps in the karstified Mesozoic basement and also initiated migration routes for hydrocarbons generated from Triassic source rocks during the Neogene subsidence and thermal maturation. Basin fills are Badenian (Middle Miocene) glauconitic sands and hemipelagic marls overlain by a 1.7–2 km thick Pannonian section, which is the main seal. The large amount of geophysical and geological data collected in the Zala basin provides an excellent 3D view for the Tertiary infill, together with the reservoir.

EVOLUTION OF ALPINE-CARPATHIAN SEDIMENTARY BASINS SEEN THROUGH DETRITAL MICA: NEW ^{40}AR/^{39}AR MICA AGES

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K-Ar ages of detrital white mica, mainly muscovite, which are preserved within sandstones in sedimentary basins of various tectonic settings are interpreted to represent formation within, or cooling through a temperature-controlled, intermediate temperature interval within the continental crust (closure temperature: ca. 300-410°C). Consequently, the residence time interval between formation of white mica, respectively cooling through the closure temperature, and the chronostratigraphic age of deposition of detrital mica in basins of various geodynamic settings can be used as an indicator for geodynamic processes in the hinterland, for example crustal rejuvenation and subsequent exhumation of metamorphic sequences during orogenesis. Predictions of the residence time in various sedimentary basins are done, and tested by confrontation with available and data from different types of sedimentary basins in Alps and Carpathians. These data monitor the throughout crustal rejuvenation within accretionary wedges and peripheral foreland (molasse) basins of Variscan continent collisional settings as the only process which lead to significant crustal rejuvenation in the area. Virtually no Alpine overprint was detected except in youngest (Late Neogene) sediments. The new data suggest that sedimentary basins can be characterized by chemical and Ar isotopic composition.

SUBSIDENCE EVOLUTION AND INVERSION OF THE KUZNETSK BASIN (SOUTH SIBERIA, RUSSIA).

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An effort was made to study the Paleozoic Kuznetsk basin, using the backstripping method in the reconstruction of basin evolution, 2D heat transfer and fluid flow modelling. This basin is an intramontane depression surrounded by the Salair Ridge, the Tom'-Kolyvan' fold belt, Kuznetsk Alatau and the Shoria Hills, filled with up to 13 km of sediments. The basin is characterized by a high heat flow (up to 80 mW/m2) and by the offset in the Moho depth up to 12 km through a major bounding faults. The backstripping method gives a spatially and temporally varying crustal/subcrustal stretching factor in the range of 2.4-3.0/3.4-3.8. Such distribution means non-uniform and multiple extensions and more intensive subcrustal deformations. Three stage of extensions were distinguished with the maximum subsidence propagation along the main axis of the basin. Because of increasing the total sediment thickness during post-rift shortening (by factor of 2/3), the predicted stretching factor seems to be overestimated. Numerical 2D experiments, including compaction, topographic and fault-driven fluid flow, have been performed to model the extensional and compressional phases. For the model where topography flow is not included, the flow velocities are decreased drastically (by a factor of 100). The temperature are not changed a lot while velocities change much. Faults that go into the basement can influence a deeper fluid flow and hence advective heat flow value.

A MANTLE FLOW MECHANISM FOR THE LARGE-SCALE SUBSIDENCE OF CONTINENTAL INTERIORS

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The geological record shows that, from time to time, otherwise stable continental interiors have experienced episodes of subsidence and uplift. The long-wavelength nature of the associated sedimentary deposits suggests that these episodes may be linked to large-scale and transient mantle downwelling events. Recent results from the mantle convection literature indicate that an instability (or instabilities) at the 660 km discontinuity may provide a plausible mechanism for these downwellings. In particular, numerical simulations show cold descending slabs pooling above the 660 km boundary and intermittently penetrating through this level. In this presentation we consider the flow dynamics of descending slabs and plumes and investigate in detail the evolving dynamic topography associated with these downwelling events. Our numerical simulations assume a multi-phase, anelastic mantle and a two-dimensional, spherical, geometry. To simulate the effect of a stiff lithosphere, temperature-dependent viscosity has been incorporated with mixed surface boundary conditions [e.g., Zhong & Gurnis, *J. Geophys. Res.*, 1994]. Our results suggest that a broad mantle downwelling event below the craton is capable of reconciling both the length- and time- scales associated with certain long-wavelength subsidence events of continental interiors.

GEODYNAMIC PREREQUISITES OF THE DEVELOPMENT OF PETROLIFEROUS BASINS IN THE WESTERN PACIFIC OCEAN

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138 sedimentary basins of which 59 are petroliferous have been recognized in the onshore and offshore parts of the region. The basins lie on the Asian and Australian cratons and their passive and active margins. Cratonic and passive margin basins are related to synectises, rift-related troughs and depressions, intra-foldbelt depressions, and foredeeps. Active margin basins are associated with backarc, interarc, forearc, and accretionary troughs.
The determining factors in the structural evolution and realization of petroleum potential of the region's sedimentary basins were the processes of Mesozoic-Cenozoic diffuse rifting on the continents and in pericratonic sag zones and the subduction of the Pacific plate beneath the Asian and Australian continental megablocks in trench zones giving rise to active continental margins. Compressive processes induced by the convergent motion of the plates broken by rifting gave rise to accretionary structures.
Rift-related sedimentary basins were usually filled with thick sediments including HC source rocks, reservoirs, and seals, and are most promising for HC prospecting. The ongoing tectonic movements in the region exert active influence on the HC generation potential of the sedimentary basins and facilitate the formation of immature oils and redistribution of preexisting pools.

The deep structure of the sedimentary basins of the Okhotsk Sea and its comparison with other sedimentary basins of the World

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The study was carried out along the geotraverse crossing the Mesozoic structures of the Sikhote Alin, the Tatar Strait Trough, the Cenozoic structures of the Sakhalin Island, the Kuril Deep Sedimentary Basin of the Okhotsk Sea, recent structures of the Kuril Island Arc, and the Mesozoic Plate of the Northwest Pacific Basin. The deep structure of the sedimentary basins of the Okhotsk Sea is compared with that of the deep troughs of the marginal seas in the western part of the Pacific and with that of the sedimentary basins of Eurasia.
The general characteristics of the deep structure of the sedimentary basins in the Okhotsk Sea are the following:
- rift structures or spreading centers at the bottom of deep basins;
- active volcanism at the initial stage of formation of a basin accompanied by hydrothermal processes and the formation of sulfide deposits;
- high heat flow values caused by the uplift of the asthenosphere towards the crust;
- the sedimentary basins overlie the heated anomalous mantle diapir rising from the asthenospheric lens. The hot mantle fluids promote the transformation of the organic matter into oil and gas in sedimentary basins and, apparently, serve as an additional source of hydrocarbons.

MULTI-SCALE STRAIN PARTITIONING AND WEDGING DURING INTRAPLATE DEFORMATIONS

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Surface and subsurface data are used here to describe the crustal architecture of two intracratonic orogens, i.e. the Merida Andes (Western Venezuela) and the Pyrenees (France-Spain), as well as localized deformations in adjacent forelands (i.e. in the Maracaibo-Barinas/Apure basins, and in Provence, respectively).
In both examples, the obliquity of inherited extensional structures relative to active compressional stresses results in strain partitioning and wedging, with the development of major stike-slip faulting within the orogen (Bocono and North Pyrenean faults, respectively), a crustal triangle architecture, and disymetric foreland-fold-and-thrust belts on both sides of the belts.
Similar wedging and strain partitioning are also observed at a smaller scale in adjacent foreland domains, with a competition between fault-reactivation and development of neoformed faults (short-cuts) during inversion processes.
In this context of intraplate dynamics, paleostress data and pre-existing structural grain (strike and dip of inherited extensional structures) are the key for the prediction of structural closures.

THE IMPORTANCE OF STRATIGRAPHIC CONTROL IN UNDERSTANDING THE LATE NEOGENE TECTONIC EVOLUTION OF SW PANNONIAN BASIN

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The Pannonian basin was an integral part of the Paratethys, a separate branch of the Tethys ocean which developed during the Oligocene to Pliocene from central Europe to central Asia. The gradual separation of this vast epicontinental basin from the world ocean system was mirrored by severe provincialism of the aquatic faunas which has long been a major source of uncertainty for biostratigraphic correlation between Paratethyan and Mediterranean events. This uncertainty has hampered, so far, a reliable interpretation of timing for the Late Neogene evolution of the Pannonian basin. Based on the integration of interpreted regional seismic profiles across SW Pannonian basin and a set of outcrop-scale seismic profiles recently acquired on Lake Balaton, Hungary, we present a new tectono-stratigraphic model for the SW Pannonian basin which relies on revised Late Miocene chronostratigraphic correlation between the Paratethys and the Mediterranean systems. Results of our work include a proposal for the institution of a new stage in the Late Miocene series of the Paratethys and the surprising conclusion that no any major paleoenvironmental impact was perceptible in the Paratethys during the Messinian salinity crisis of the Mediterranean.

THERMAL EFFECT OF THE CENTRAL BOHEMIAN GRANITIC PLUTON (CZECH REPUBLIC) ON THE ADJACENT SEDIMENTS: RESULTS OF COMPUTER SIMULATION

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Vitrinite reflectance, illite crystallinity and fluid inclusion survey of the Lower Paleozoic Barrandian basin has shown that the sediments, which are now only shallowly burried (uppermost 1 km) have undergone medium to high levels of diagenesis and experienced temperatures in the range of 90-180 deg C. Because the present heat flow and temperature gradients are about 60 mW/m2 and 20-30 K/km, respectively, the estimated levels of diagenesis imply substantially higher heat flows and/or thicker overburdens in the history of the basin. Another possible source of the increased temperature, however, may have been the Central Bohemian Pluton - a large Variscan granitic intrusion outcroping 25 km SE of the basine. We simulated the thermal effect of this igneous body by solving numerically transient heat conduction equation in the two 2-D geothermal models perpendicular to the basin's axis. The assumed surface heat flow, temperature of the intrusion and the heat of crystallization were 60 mW/m2, 800 deg C and 315 kJ/kg, respectively. Whereas the maximum temperature increase at 2 km distance from the intrusion appeared 0.2 Ma after the intrusion emplacement and reached about 170 K, the increase at the basin's rim culminated 1.5 Ma after the emplacement and attain at most 8 K. The direct thermal effect of the pluton on adjacent Lower Paleozoic sediments was therefore comparatively negligible.

TECTONIC STRESS AND ITS INFLUENCE ON FLUID FLOW: A CASE STUDY FROM THE MID-NORWEGIAN MARGIN

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The post-Eocene tectonic evolution on the mid-Norwegian margin is characterized by thermal subsidence that was interrupted by periods of intraplate compression. Contractional deformation resulted in the development of arches, domes and regionally uplifted domains where the geographical position of these areas was controlled by spatial variations in lithospheric strength. In this paper we examine the influence of Tertiary uplifts on caprock and fault sealing properties based on information from geophyscial well logs and reflection seismics combined with predictions from finite element modelling. The sealing properties of faults and caprocks vary significantly in the area as evidenced from the overpressure distribution and hydrocarbon findings. Compaction trends derived from log data indicate that wells located in the vicinty of major faults on parts of the margin have experienced additional (localized) uplift. Several of these wells have proven to be in absence of hydrocarbons which suggest a close link between tectonically induced uplift and leakage of hydrocarbons. Providing constraints on processes of mechanical deformation, finite element models have been used to further evaluate the causal relationships between rock deformation and fluid flow. Results are presented for predictions of stress-fault interactions and of stress and fracture distribution in reservoir and caprock sediments.

THERMAL MODELLING OF MATURATION IN RIFT-RELATED BASINS

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The change of paleoheat flow in time in a rift-related basin is modelled in combination with a consideration of the effect of suppression of vitrinite reflectance upon oil generation. The area of interest in this study is the North Viking Graben and modelled as a comparison is another rift-related area, the North West Shelf, Australia. The results imply that if the effect of suppression is neglected in combination with an erroneous paleoheat flow history the maturity could be severely underestimated. This is one more than likely explanation for the lack of success in the exploration of oil in the western region of the North West Shelf, Australia.

GEODYNAMICAL AND THERMAL RIFT EVOLUTION: NEW RESULTS FOR DNIEPER-DONETS BASIN

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A method of setting up a unified dynamic and geothermal lithospheric model has been set up as a result of the solution of a coupled system of differential equations of dynamics of the block-structured geophysical medium and a 2D heat transfer equation. In the time domain the models enable us: 1) to study dynamics and faulting of the upper crustal layer blocks with considering sedimentation and erosion phenomena; 2) reestablish the picture of the evolution of the thermal regime of the lithosphere; 3) estimate the role of tectonic and geothermal factors in processes of rift formation and post-rift state of the basin. The practical efficiency of the method is illustrated on an example of the constructed model of the formation and evolution of the NW Dnieper-Donets basin along the regional profile Mala Devica-Bakhmach. These results are compared with those published earlier for the same profile for studying the rift and early post-rift development of the region.

MULTIPLE EPISODES OF FLUID MIGRATION ACROSS THE BOHEMIAN MASSIF : EVIDENCE FROM BITUMEN REFLECTIVITY AND HYDROTHERMAL KARST

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Recent integration of structural, seismic and petrological data has shown that sedimentary and crystalline units of the Bohemian Massif are penetrated by a series of major north-south trending faults and fractures that were instrumental in focussing and transporting warm fluids. The movement of fluids along the faults has occurred episodically throughout geological time and may have been tied to the earthquake cycles. In particular, in the Barrandian Lower Paleozoic basin of central Bohemia, petrological and fluid inclusion research on north-south trending calcite veins indicates extensive migration of petroleum bitumens and saline brines followed by Variscan thermal overprint. Post-Variscan warm fluids that have reactivated these migration pathways, also transported liquid hydrocarbons and were responsible for the development of hydrothermal caves. Explosive kimberlite pipes of Tertiary age, deposition of Quaternary spring limestones and numerous discharges of thermal and/or mineral waters located elsewhere along the north-south striking lineaments are probably indicative of youngest stages of fluid activity which may have locally persisted until the present time.

EROSION/SEDIMENTATION MODELLING OF THE MAAS CATCHMENT IN RELATION TO CLIMATE AND TECTONICS

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This research is carried out in the framework of the Neesdi program which is targetted towards the analysis and modelling of the interplay of natural processes affecting the environment at the earth's surface, focussing on the situation in the Netherlands. This subproject of the Neesdi program concentrates on the geological history of the Maas/Meuse river system in Belgium and the Netherlands during Quaternary. The research aims at determining the influences of tectonic movements, climate and internal river dynamics on sediment budget and behavior of the river system. Cimatic oscillations during Quaternary have led to phases of incission and aggradation of the river system. The resulting terraces are best preserved in the southern part of the Netherlands. The Maas/Meuse river system was also influenced by differential tectonic movements consisting of the uprising Ardennes and subsiding Central Graben. These tectonic movements started during Late Oligocene. During the Middle Pleistocene the uplift of the Ardennes accelerated, leading to increased incision rates and sediment delivery to the Central Graben area. The uplift also affected the Central Graben area and had a major impact on the course of the river system. In this presentation we will focus on the impact of Middle Pleistocene tectonic event on the dynamics of the river system and we will discuss several tectonic mechanisms for the uplift event.

SEDIMENTARY BASINS FORMATION AND EVOLUTION. CASE STUDY OF THE PRE-CASPIAN DEPRESSION AND SEDIMENTARY BASINS OF BRAZIL.

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The origin and evolution of sedimentary basin could be a clue for oil-gas deposits forecasting. For simulation of the basin evolution and pressure and heat flow density distribution the thermomechanical modelling was used. Thermomechanical modelling together with field investigations and wells data gives the possibility to research the geothermal field changing during the sedimentary basin evolution. All geological, geophysical and petrological data were used for sedimentary basins evolution modelling. Different sedimentological models were used for analysing of sedimentary cover formation and evolution. The Pre-Caspian Depression is a unique structure of ancient platforms with sedimentary cover near 24 km. Genesis and evolution of the Pre-Caspian Depression are explained by upwelling of a mantle diapir. The existence of mantle diapir could be confirmed by gravity, electromagnetic and geothermal data. The specific form of the basins in Brazil could be explained by round form of mantle diapir in Maranhao Basin, interaction of Pacific-South American plates collision with mantle upwelling for Parana Basin and rift form of mantle activity with separate round smaller diapirs for Amazon Basin.

Present-day lithospheric strength of the Norwegian continental Vøring margin and predictions of Late-Tertiary deformation.

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Various strength envelopes have been calculated along different transects through the Vøring margin. Thicknesses of the individual layers, Moho depth and strain-rate strongly control the steepness of the geotherm and the strength of the lithosphere. Modelling shows strong variations in lithospheric strength from NW to ESE through the Vøring margin. From the Northern Vøring Marginal High (ocean edge) to the margin centre, a decreasing strength has been calculated throughout the whole lithosphere with a pronounced decoupling of strength in the Upper-and subcrustal lithosphere in the margin centre. From the centre towards the south-eastern border of the Vøring margin (Halten Terrace and Trøndelag Platform) an increasing strength is observed. These variations are primarily caused by thermal blanketing due to thick shale sequences with relatively low conductivity with maximum thickness in the centre of the margin. Low strength is further enhanced by elevated heatflow in the margin centre. For the sediments on the margin a reduction of the friction angle as well as an increasing hydrostatic pore fluid pressure leads to a further reduction in the upper-crustal strength. Assuming uniform stresses, our modelling results predicts localization of Late-Tertiary deformation in the margin centre were the crustal strength is lowest. This is largely in agreement with observations.

THE INFLUENCE OF A STRATIFIED RHEOLOGY ON THE FLEXURAL RESPONSE OF THE LITHOSPHERE TO (UN)LOADING BY EXTENSIONAL FAULTING

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We present a two-layer finite difference model for the flexural response of the lithosphere to extensional faulting. The model allows for three modes of flexure: (1) fully coupled, with the upper crust and mantle welded together by the lower crust, (2) fully decoupled, with the upper crust and mantle behaving as independent layers, and (3) partly decoupled, signifying that the response of the upper crust to small-wavelength loads is superimposed on the response of the entire lithosphere to long-wavelength loads. Which of these modes of flexure is to be expected depends on the rheology and especially the thermal state of the lithosphere. Coupled behaviour is related to a cold and strong lithosphere. The Baikal Rift zone provides a typical example for this mode of flexure. A fully decoupled lithosphere is an exceptional case, related to anomalous high temperatures in the lower crust, and is observed in the Basin and Range province. The most common case is a partly decoupled lithosphere, with the degree of decoupling depending on the thickness and viscosity of the lower crust. This is inferred for example for the Bay of Biscay margin.

CONTROLS OF PRECEDING TECTONIC HISTORY ON NEO-TECTONICS AND EARTH QUAKES IN THE ROER VALLEY GRABEN (THE NETHERLANDS): CONSTRAINTS FROM RHEOLOGICAL AND FINITE ELEMENT MODELLING

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Rheological predictions for phanerzoic basins indicate a pronounced decoupling of upper crustal deformation from subcrustal levels. As a consequence the structural expresion of basins is primarily controlled by the movements along weak upper crustal faults, interacting with the rheological behavior of the uper and lower crust and basin infill. With the aid of Rheological and Finite element modelling we analyse the role of this rheological interaction, and in particular the potential role of pre-existing weak faults, using the Tertiary and Neo-tectonic evolution of the Roer Valley Graben as a natural laboratory. Rheological modelling results show that observed basin reactivation in the Roer Valley Graben requires permanent weakening of the lithosphere, in which relative weak major normal faults (border faults), marked by reduced friction angle, play an eminent role. This is confirmed by finite element models which clearly show that Tertiary basin architecture is mainly determined by relatively weakness of border faults compared to other faults. Further relevance of predicted stress and strain distribution will be discussed in the light of observations of near surface expression of faults, seismic activity and predictions for postseismic slip.

FLUXES AND GEOCHEMICAL BALANCE OF CARBON IN THE OCEAN

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The results of analysis of data obtained in P.P.Shirshov Institute of Oceanology are presented on distribution and masses of organic (Corg) and nonorganic carbon in various regions of the World Ocean and in its main structural- geomorphological zones in dissolved and particulate form, upper sedimentary layer (0-5 cm), biomasses and production of phytoplankton, input from land (river discharge, subterranean runoff, glacial runoff, eolian transfer, wave abrasion material). Model maps of Corg distribution in recent bottom sediments and fluxes of Corg to sediment-water interface were constructed. Total flux of carbon from land in the World Ocean is evaluated as being equal to (658 and 870) x 1012 g C for organic and nonorganic carbon respectively. Rivers discharge of dissolved (210 and 502) x 1012 g C / year and particulate (250 and 168) x 1012 g C /year carbon and eolin transfer (174 and 21) x 1012 g C /year make principal contribution in this flux. New data are grounded on bioproductivity of the ocean (60 x 1015 g Corg /year) and amount of carbon deposited in marginal (150-240 and 584) x 1012 g C/year and pelagic (10 and 285) x 1012 g C/year regions of the ocean. Fossilisation coefficients of Corg were estimated for bottom sediments of marginal regions (0.8-1.3%), ocean floor (0.02%) and the whole ocean (0.3-0.4%).

STRUCTURE OF THE LITHOSPHERE BENEATH THE DNIEPER-DONETS BASIN, UKRAINE, ACCORDING TO GRAVITY DATA

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Dnieper-Donets Basin (DDB) is a linear Late Palaeozoic depression of SE-NW orientation on the East-European platform separating the Ukrainian Shield and Voronezh Massif. It consists of two main parts: Dnieper graben - typical rift basin and Donbas Foldbelt (DF) - inverted part of the basin. 3-D gravity analysis, using a gravity backstripping technique, had been carried out in order to investigate deep structure below the basin. Residual gravity field I, obtained by subtracting the gravity influence of the sedimentary succession from the observed field, reveals a distinct positive anomaly along the basin axis. Residual gravity field II (gravity effect of a homogeneous crystalline crust been removed from residual field I) reaches 200 and 100 mGal amplitude in DF for two Moho models (differed by Moho depth below DF) based on different interpretations of seismic data. For each residual anomaly II, the best fitting 3-D distribution of average density in the crystalline crust has been computed. Both models show the existence of a high density body in the crystalline crust along the DDB axis, increasing in density from the Dnieper graben to DF. The density increase within the crystalline crust may by explained by intrusion of mafic and ultramafic rocks during Late Devonian rifting although further reworking of the crust during Permian tectonism in the DF cannot be ruled out.

T_E ESTIMATES BENEATH PALEOZOIC-MESOZOIC PARANÁ AND PARNAÍBA BASINS, BRAZIL

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The Paleozoic-Mesozoic Paraná and Parnaíba basin - Brazil, shows many similarities: evolution, Mesozoic magmatism, basement geology and Bouguer gravity signature. Although these basins have been the focus of many studies in several different areas, their origin is still a matter of debate, nevertheless there is general agreement that magmatism and thermal subsidence of the scale seen specially in Paraná basin requires continental rifting. Coherence analyses provide a means to investigate lateral variations in isostatic compensation beneath the basins that are probably related to lithospheric structure. Effective elastic thickeness (T_e) estimates beneath the Paraná and Parnaíba basins indicate variations from $\sim$ 50 km for the broad basins to less than 30 km to areas where the Bouguer gravity signature is characterized by a relative low, narrow and steep gradients. If interpreted in terms of thermal age, these T_e estimates suggest the thermal age of the lithosphere of $\sim$400 Ma and $\sim$200 Ma which corresponds, respectively, to the age of the oldest sequences within both basins, and the volcanism within the basins which are generally associated to the opening of the South Atlantic ocean. The T_e results obtained in these studies are comparable to estimates for Mesozoic rift basins in Africa and Australia, raising questions about lithospheric heating during plume events.

Mechanical controls on collision-related compressional intraplate deformation.

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Stresses related to collisional plate coupling appear to be responsible for the most important compressional intraplate deformations. For the build-up of intraplate compressional stresses, four collision-related scenarios are envisaged: 1) during the initiation of a subduction zone along a passive margin or within an oceanic basin, 2) during subduction impedance caused by the arrival of most bouyant crust, such as an oceanic plateau or a microcontinent at a subduction zone, 3) during the initial collision of an orogenic wedge with a passive margin, depending on the lithospheric and crustal configuration of the latter and the presence or absence of a thick passive margin sedimentary prism, as well as convergence rates and directions, 4) during post-collisional over-thickening and uplift of an orogenic wedge. The build-up of collision-related compressional intraplate stresses is indicative for mechanical coupling between an orogenic wedge and its forelands. Localization of collision-related compressional intraplate deformations is controlled by spatial and temporal strength variations of the lithosphere in which the thermal regime, the crustal thickness, the pattern of pre-existing crustal and mantle discontinuities, and sediment loads and their thermal blanketing effect play an important role.

SE9 Combined geophysical and geochemical approaches to study mid-ocean ridges

Convener: Bonatti, E.
Co-Convener: Hekinian, R.

MANTLE THERMAL ANOMALIES INFLUENCE THE STABILITY OF BOUVET TRIPLE JUNCTION

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The Bouvet Triple Junction (BTJ) is where the South American, the African and the Antarctic lithospheric plates meet in a geologically complex region of the South Atlantic near the island of Bouvet. Multibeam morphobathymetry, magnetometry, gravimetry and seismic reflection data were acquired in this region during two expeditions in 1994 and 1996, that obtained also abundant recoveries of bottom rock samples. These new data help understand the characteristics and evolution of the three accretionary/transform boundaries that converge in the BTJ the America Antarctic Ridge (AAR), the Mid Atlantic Ridge (MAR) and the South West Indian Ridge(SWIR). Strong melting anomalies characterize the two westernmost segment of SWIR. The segment adjacent to Bouvet island is shallower than normal by almost 1 km. probably due to the influence of the Bouvet hot spot. The westernmost SWIR segment (Spiess Ridge) is highly anomalous: it consists of a major volcanic system, elongated NW-SE and roughly 50 km wide. We estimate that the Spiess magmatic event started roughly 1 my ago. A broad !!sheared zone¶ and an area of intense extensional deformation has been observed east of Spiess Ridge and north of the Bouvet Transform. This intraplate tectonic deformation is probably caused ultimately by excess crustal formation at Spiess Ridge. The thermal anomaly that gave rise to the SWIR-Spiess excess magmatism is the prime cause of the recent disruption of a former RRR Triple Junction configuration, and of the imminent establishment of a new configuration. The geochemistry mantle derived peridotites and basaltic glasses recovered from this region support the hypothesis of intense thermal anomalies in the mantle below the Bouvet triple junction.

SE9

ABUNDANCE OF SERPENTINIZED PERIDOTITE IN THE LOWER OCEANIC CRUST FROM SEISMIC VELOCITIES

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The use of compressional- and shear-wave velocity data from laboratory and seismic refraction experiments are not sufficient to discriminate between an oceanic crust composed mostly of gabbro or peridotite. I have analyzed available compressional- and shear-wave velocity data at different pressure ranges. The results have been used to produce crustal models with different abundances of gabbro and peridotite, and that are consistent with the seismic velocity profiles. Overall, the results demonstrate that seismic layer 3 could show a crustal composition ranging from ~15% to ~75% partially serpentinized peridotite, and have identical seismic velocities. This pattern is observed in both Pacific and Atlantic crust, and no differences in predicted crustal composition can be observed. Serpentinite is not a volumetrically very abundant (<30%), but may have important mechanical effects in the oceanic lithosphere. These results demonstrate that a) lithological interpretation of seismic velocity data requires additional geological and geophysical information, b) that serpentinized peridotite may in fact be an important component of seismic layer 3, and c) that the seismic crust cannot be equated to magmatic crust without independent constraints on crustal composition.

CORRELATIONS BETWEEN GEOPHYSICAL AND GEOCHEMICAL OBSERVABLES ALONG THE MID-ATLANTIC RIDGE : SLOW-RIDGE/HOTSPOT INTERACTIONS

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Geophysical observables are sampled from global data sets across the Mid-Atlantic Ridge (MAR), close to the Azores (AZR), Ascension (ASC), Tristan da Cunha (TRS) and Bouvet (BVT) hotspots. The axial bathymetry and across-ridge topography, the axial and amplitude of the free-air anomaly are determined along evenly spaced 200 km-long profiles. These observables are plotted vs. the cumulative distance along the ridge, together with the upper mantle S-wave velocity anomaly, the filtered geoid and the 87Sr/86Sr ratios. Spatial correlations between all these observables shed some light on the interactions between the hotspots and the MAR : 1) maxima of observables are located 150 km south of the ridge section closest to ASC, this hotspot being too weak influence notably the MAR 2) Only relative maxima are superimposed over a long-wavelength trend, over the ridge section close to TRS, indicating a recent decrease in the interactions of TRS with the MAR. 3) A large asymmetry in the upper mantle structure dominates the influence of the AZR hotspot on the MAR. The above correlations strongly constrain ridge/hotspot interaction models. They are presently being supplemented by the analysis of recent seismicity along the MAR, provided by high-quality global networks.

Natural electric field, Eh and pS anomalies over the Logatchev site (MAR, 14°45'N): influence of buoyant plume or low-temperature degradation of the ore body?

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In the 7th cruise of R/V Professor Logatchev the anomalies of natural electrical field (NF), Eh and pS using towed instrument package (RIFT) were discovered at 14 45'MAR (Logatchev hydrothermal field). The RIFT was towed 15 and 40 m above the sea floor. Anomalous zone (AZ) is situated close (10-30 m) to two low-temperature venting areas of degrading sulphides and a black smoker Irina-Microsmoke forming a distinct buoyant plume. Over or close to the main area of high-temperature venting situated to the south-east from the AZ no NF and Eh anomalies were observed. According to the results of Mir dives the higly mineralized solutions from smoking craters at the main mound form non-buoyant plumes (reverse-plumes) mostly. The NF anomaly was crossed on two levels of the low part of the buoyant plume characterized by the high concentration of Fe sulphide particles, low redox potential and S concentration in bottom waters. The low-temperature alteration of sulphides with biogeochemical processes involved also may cause the anomalies of the NF. But the Eh and pS in this case must be much higher than it was measured.

ONE MORE EXPLANATION OF RELATIONSHIPS PLAGIOGRANITES AND HOST GABBROIC ROCKS IN SLOW-SPREADING RIDGES.

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A simplified petrologic model of the oceanic lithosphere creation suggests that leucocratic igneous rocks associated with Mid-Oceanic Ridge gabbro are late members of layered magmatic series and formed by fractionation of MORB produced magmas. This study is intended to outline magmatic relationships oceanic plagiogranites and host gabbro and to examine their genetic conformity. Samples selected for this study were obtained during dives of submersble "Nautile" in the Rift Valley of MAR near 15°20'FZ. Granites from MAR segment examined form thin veins in host gabbro; residual peridotites are present at same site also. These rocks correspond to throndjemites and consist of albite, biotite, quartz, secondary actinolite and include small resorbed xenoliths of host gabbro. Composition of biotite in both group rocks allow us to suggest that its variations depend on change of temperature and alkalinity during magmatic interaction of late trondhjemitic melts and host gabbro. Throndjemites characterized by strong enrichment of LREE : $(La/Sm)_{cn}=3.3-4.2$, and $(Ce/Yb)_{cn}=5.4-10.9$. REE distribution in these rocks does not correspond to one in plutonic suites related with MORB. At the same time, host biotite-bearing gabbro is sufficiently enriched by LREE in comparison with associated biotite free gabbro : $(Ce/Yb)_{cn}=2.6$ and 1.6,.consequently). This study shows that at least two different types of plagiogranites are present in Mid-Oceanic Ridges: the first one has genetic relationships with host gabbro and second one does not relate to host gabbroic rocks and originated from other magmatic sources characterized by anomalous geochemical features perhaps.

Geochemical and geophysical evidence of the different stages of hydrothermal activity at some segments of the East Pacific Rise.

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Existing geophysical and geochemical data as well as our observations during the R/V Morskoy Geolog Leg 3 on the EPR segment and its flanks at 11-14° N, SOJOURN-II cruise (R/V Meiville) along the EPR crest at 17°15'-18°30'S, R/V Geolog Fersman Leg 4 on the EPR at 21°20'-22°40'S show high correlation between some of such parameters as the position of the seismic reflector, intensity of magnetic anomalies, magnetic properties and petrochemical features of young basalts sampled from or near the crest of the EPR, geochemical variations of axis lava compositions (MgO, K and Fe contents), distribution and style of hydrothermal activity. The detailed study of magnetic properties of different parts of the same sample from 13° N shows the correlation of the magnetic properties and the degree of basalt crystallization. The distribution of vents at 17,5° S appears to reflect 4th order ridge segmentation/magma supply. At 21,5° S within the magnetic anomaly mostly Fe-rich varieties were sampled. A possible scenario for the ridge evolution of the distinct EPR hydrothermal areas is proposed.

GEOLOGICAL AND GEOPHYSICAL PARADOXES OF THE MID-ATLANTIC RIDGE (MAR) DEEP STRUCTURE

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Gravimetric investigations showed the presence of numerous thick-crusted (up to 40-50 kms thick, similar to continental) low-density blocks both in the axial and peripheral MAR regions: Western MAR wing at 10-13°S, 8-10°N near Equator, etc. Within these ancient (Mesozoic?) limestones (Vema [Bonatti, 1971]) and even more ancient (more than 1,800,000 yrs) migmatite-granites (Doldrams fault [Troukhalyov, 1992]) were found. It was shown that flank (non-rift) magmatism is widely distributed [Pussharovskii et al., 1988] and that in many cases, transform zones are the sources of fresh basalt lava (Chain, Kane and Vernadsky fracture zones, FZ). Compression and stretching stress was found in the Romanche and Vernadsky FZ. Taken together with the density and magnetic asymmetry of the wing crust [Budanov, 1977, 1980, 1997, Gorodnitskii, 1994, 1995.] this suggests the inadequacy of a simple, unique model of MAR development. Alternative models should be forwarded and discussed which could account for all the complicated and diverse, often paradoxical phenomena (geological, geophysical and geochemical) related to MAR. Some of these models are discussed in the report.

CORRELATIONS BETWEEN DEEP SEISMIC VELOCITY ANOMALIES AND ISOTPE RATIOS OF MORB ALONG THE MID ATLANTIC AND WEST AND CENTRAL INDIAN RIDGES

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We present an investigation of the relationship between seismic velovity anomalies in the mantle and the isotopic ratios of MORB. The 3D tomographic models provide a full coverage of the globe with limited resolution at short wavelengths. Conversely, geochemical data, sampled in a limited number of sites, do not gives acces to long wavelengths. The North Mid Atlantic Ridge (MAR), south west and Central Indian (SWIR and CIR) offers a common domain, both in space and wavelength, where a comparision can be performed. These ridges define a total path of about 20000 km with limited gaps in the geochemical sampling. In the upper mantle, we only observed a poor correlation close to 700 km depth (not fully significant) along the MAR. This correlation vanishes in the lower mantle. At 2500 km depth, the correlation increase notably, and become fully significant close to the core mantle boundary. In the south atlantic and indian oceans, we observed a general increase of both the Sr87/Sr86 ratio and of the seismic velocity at 2800 km depth when heading south (MAR) or East (Indian) We briefly discus the possible interpretations of these correlations.

A COMPARATIVE ANALYSIS OF THE MID-ATLANTIC RIDGE AREAS WITH SYMMETRICAL AND ASYMMETRICAL GEOPHYSICAL CHARACTERISTICS OF THE WING CRUST.

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Symmetrical elements in crust geometry, density and ΔT can be found in some segments of the Mid-Atlantic Ridge (MAR) as described elsewhere. Therefore, a spreading model can be used to describe the mechanism of formation of these zones. However, we conclude that neither this model nor its modifications can be applied to the vast MAR regions surveyed by us (more than 20 geophysical profiles crossing MAR from 13°S to 72°N). This conclusion is based on the two fundamental facts: Western and Eastern wings of the ridge are often asymmetrical both in their crust density (2,4 and 2,75 g/ccm, respectively) and in their thickness (the Western wing crust is approximately twice as thick as the Eastern wing crust). In this thick Western wing crust (up to 50 kms) basalts form only a thin upper layer. The disruption of bilateral symmetry of ΔT was also observed in the vast MAR areas [Gorodnitskii, 1994, 1995]. And finally, it was shown that the mean heat flow value within the Western wing is considerably higher than that within the Eastern wing (60 and 40 mW/sqm, respectively) [Podgomykh, 1996]. Thus it is clear that a simple single model of crust formation (such as spreading) cannot account for this complicated process in all Atlantic areas and the more sophisticated mechanisms should be proposed. These are presented and discussed in our report.

SE10 Fault interaction and earthquake mechanics

Convener: Das, S.
Co-Convener: Cocco, M.

NEOTECTONIC EVIDENCE FROM FIELD STUDIES OF RECENT FAULTING IN THE SOUTH ICELAND SEISMIC ZONE (SISZ)

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Most destructive earthquakes in Iceland have occurred in the SISZ. We collected about 700 brittle tectonic data at 25 sites in Late Pliocene to Holocene basalts and hyaloclastites. At each site, the whole data set reveals two opposite stress regimes, each including normal and strike-slip faulting. The analysis of the strike-slip fault in the major data subset indicates paleostress tensors with subhorizontal $\sigma 1$ and $\sigma 3$ axes, the trend of $\sigma 3$ being N270°E to N340°E (main trend: N315°E). The normal faults in the major subset characterize vertical $\sigma 1$ and horizontal $\sigma 3$ also trending N270°E to N340°E. In the minor data subsets, the direction of $\sigma 3$, for the strike-slip faults as well as the normal ones, ranges from N20°E to N80°E (N45°E on average). The major stress regime includes 70% of the total population of faults. Of a total of 718 fault slip data, 55% indicate primarily normal-slip and 45% primarily strike-slip. The ratio normal/strike-slip faults is lower than in other areas in Iceland. Moreover, many normal faults were generated in the western rift-zone segment, then drifted out of it. The above results indicate that the dominating stress field in the SISZ favours strike-slip faulting, with an horizontal $\sigma 3$ axis trending approximately WNW-ESE to NW-SE. We point out, however, that in addition, there is a contrasting minor, stress field, characterized by approximately NNE-SSW to NE-SW extension. These results were compared to the stress regimes determined from earthquake focal mechanisms. This comparison reveals that the paleostress and stress regimes are identical and that the changes in the stress field of the SISZ are characterized by stress permutations between $\sigma 1$ and $\sigma 2$ and between $\sigma 1$ and $\sigma 3$.

SEISMOGENIC STRESS FIELD IN THE SOUTH ICELAND SEISMIC ZONE

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In the South Iceland Seismic Zone, the determination of the stress regimes is done through calculation of stress tensors, involving the use of inverse methods. Preliminary analyses of ocal mechanisms recorded by the S.I.L. network revealed the presence of two contrasting stress regimes (Angelier *et al.*, 1996, *in* « Seismology in Europe », European Seismological Commission, Reykjavik, p.199-204).
A major NW-SE extension is in agreement with the left-lateral behaviour of the E-W seismic zone. A minor NE-SW extension is attributed to rebound phenomena, local block accommodation and magmatic effects. For both these regimes, strike-slip mechanisms prevail, many normal and few reverse mechanisms being also present. Permutations between stress axes, σ_2/σ_3 and σ_1/σ_2, are common.
The crucial problem of the choice between nodal planes of double couple focal mechanisms is solved in two ways. First, some methods do not require the choice between the nodal planes, such as for the right dihedra (P- and T- dihedra) method. Second, for those inversions requiring choices between nodal planes, and because the earthquakes studied are very shallow, the rich geological information on the fractured medium deserves attention. We use an integrated approach including four criteria: geophysical and geological: consideration of nodal plane attitudes as compared with geological discontinuities, comparison with recent fault mechanisms observed in the field, consideration of mechanical likelihood for each fault solution, and best fit criterion relative to the stress tensors calculated.
The systematic use of these criteria for nodal plane selection within a weighted approach (reliability, magnitude, depth, etc.) allowed better determination of the stress regimes in the SISZ.

CONTACT LOSS DURING STICK-SLIP: FROM EXPERIMENTAL EVIDENCE TO INSIGHTS FOR SEISMIC BEHAVIOUR.

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Following the ideas that interface vibrations could give a possible explanation for some problems in earthquake mechanics (Brune et al., 1993) and that stick-slip is considered as an analogue of seismic rupture (Brace and Byerlee, 1966), a detailed measurement of the normal displacement during stick-slip can give insights for seismic behaviour.
We present experimental results demonstrating that sliding surfaces are separated during stick-slip under a wide range of normal pressure (between 10 and 50 MPa) and roughness (between 3 and 128 µm RMS value) using a PMMA material analogue.
Results show that a normal displacement occurs during and after the slip phase. At 50 MPa for smooth surfaces, the maximum normal displacement during the slip phase was found to be higher than the maximum value of the peak-to-trough relief of the surface, showing the evidence of contact loss. In other conditions, the maximum normal displacement was higher than the RMS value implying a contact loss on most of the surface. Another very important observation, made in some experiments, is that the normal displacement fluctuates during the slip phase. This has been interpreted as elastic rebound between sliding surfaces.

CLUSTERING AND SIZE DISTRIBUTIONS OF FAULT PATTERNS : THEORY AND MEASUREMENTS

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The fractal geometry of fault systems has been mainly characterised by two scaling-laws describing either their spatial distribution or their size distribution. However, the relationships between the exponents of both scaling-laws has been poorly investigated. From a theoretical analysis, we show that both exponents are related through a new simple relation involving the distance from a fault to its neighbours. Moreover, we propose to introduce another scaling-law to describe the possible correlation between the position of a fault, its length and its nearest neighbours. Measurements of the relevant exponents on simulated and natural fault patterns are in very good agreement with the theoretical analysis. In particular, we show statistically that the geometrical characteristics of different neighbours are clearly correlated, certainly because of the mechanical interactions involved during faults system dynamics.

MODELING OF DEFORMATIONS EARTHQUAKE PRECURSORS IN ACTIVE FAULT ZONES.

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Quantitative model of formation of a deformation earthquakes precursors in active fault zones was elaborated. The model is based on the theory of elastic inclusions (model analogues for earthquake focus zones and active faults).
Unhomogenius geological medium is modeled system of prismatic inclusions with decreased mechanical properties (i.e. fault zones).
Mechanism parametrical intensification of precursors deformations in fault zones was elaborated. Results of modeling is compared with leveling measurements obtained during period of earthquake preparation processes (for example earthquake March 2, 1992, M_L=7.1, Kamchatka region, Russia) and good reproducibility is demonstrated.
New technology for study precursors deformations in active fault zones with using classical geodetic methods is proposed.

DYNAMIC VERSUS STATIC STRESS CHANGES: INFERENCES ON THE EARTHQUAKE NUCLEATION PROCESS

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Fault interaction and earthquake triggering caused by coseismic ruptures have been recently studied either with dynamic or static stress changes. We have investigated the spatio-temporal evolution of the dynamic stress outside a rupturing extended fault. The stress time history evolves, after a transient phase, to the final static stress value. The application to the 1980 (M 6.9) Irpinia normal faulting earthquake is particularly interesting because the first two subevents are separated in time by 20s, while a third subevent occurred 40s after the rupture onset. The dynamic stress changes caused by the rupture of the first subevent show that the peak of dynamic stress on the 20s fault plane is reached within 8.75 sec from the rupture initiation. The static level is reached on the 20s fault plane after 13.75 s. Thus, the dynamic rupture did not jump from a rupturing segment to the adjacent one immediately, but the triggering of the subevent is delayed by nearly 10s. This time delay seems to be too long to be intepreted as the duration of a nucleation phase. However, it can be explained in terms of a frictional instability model, if the frictional properties of the subevent fault are relatively weak.

LOOKING FOR SUPERSONIC RUPTURE VELOCITIES .

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The recent dynamic simulation of the 1992 Landers earthquake performed by Olsen et al. (Science, december 1997) has shown a strong variation of the rupture front velocity from subsonic to supersonic values. Supersonic velocities were not expected from kinematic inversions of recent well studied earthquakes. Two reasons could explain why the evidence of such supersonic values are sparce in past inversions. First there is a trade off between slip amplitude and rupture time that affects solutions based on seismic data alone. Therefore it is necessary to constrain the slip amplitude distribution by independant data in order to recover the temporal details of rupture propagation. Second, a priori constraints introduced by the parameterisation used in the inversions usually constrain the maximum value of the rupture front velocity. To solve these problems, SAR interferometric data are used to obtain high resolution slip amplitude models. Then strong motion data are inverted through an inversion where the slip distribution and his error are constrained by the results of the geodetic inversion and the rupture front velocity varies freely without constrains to fit the seismic data.

METHOD FOR MULTI-SCALE STRUCTURAL AND TEMPORAL ANALYSIS OF EPICENTRAL DISTRIBUTION OF AN EARTHQUAKE SEQUENCE USING ANISOTROPIC WAVELETS

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Investigation of multi-scale spatial organization of earthquake aftershocks sequence is proposed to identify seismically active planes, and to investigate interactions of rupture propagation and the highly fractured uppermost crust. An efficient method, namely the Normalized Optimized Anisotropic Wavelet Coefficient (NOAWC) method has been developed to exhibit among a set of hypocentres the significant structures linked to seismically active rupture planes. This method is based on the 2D anisotropic wavelet transform which permits the detection of organized structures in a plane regardless of its size, location, shape anisotropy and orientation. Further, the method intrinsically accounts for uncertainty in the location of the seismic events and does not require geological presuppositions. Results of the NOAWC method on the data set of the M = 5.1 Arudy earthquake sequence (02/29/80, western Pyrenees) a posteriori combined with seismic and geomorphologic data, allow us to reconstruct the 3D geometry of the active fault-planes, and underline the seismic features linked to the regional tectonic and geomorphologic processes. In addition, the NOAWC method also makes it possible to depict rupture propagation with time, a fundamental step for understanding the physics of the earthquake generation process.

A MODEL OF FAULT INDENTATION

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Spatial inhomogeneities in friction play a dominant role in fault mechanics. A nonplanar fault model is proposed, having two protrusions which may come into contact. The relative motion of fault faces produces the contact and indentation of the protrusions with the formation of an asperity. As a consequence of fault motion, the fault faces at the asperity undergo an elastic deformation. The stress field is calculated. Deformation increases with time until the maximum shear stress is less than the limit of elasticity of rocks; beyond this limit, rock is fractured and fault gouge is produced. The volume of gouge is evaluated as a function of the asperity size and the degree of indentation of protrusions.

STRESS CHANGES IN THE SUBDUCTED PLATE CAUSED BY LARGE, SHALLOW, THRUST EARTHQUAKES: AN APPLICATION TO THE BENIOFF ZONE OF MEXICO

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Benioff zone of the subducted Cocos plate, between 99 and 102 degrees W, below the coast of Guerrero, Mexico, commences with a shalow angle, starts unbending at about 100 km from the trench and becomes subhorizontal, reaching a depth of 50 km at a distance of about 300 km. Although most moderate and large normal-faulting, intermediate-depth earthquakes in this region occur in the subducted slab far from the coast, some significant normal-faulting events are located close to the coast, just below the downdip edge of the large magnitude thrust rupture plane. Contrary to what is generally observed, these normal-faulting events are preceeded by large, shallow thrust earthquakes. This suggests a causal relationship between the thrust and the normal-faulting events. To explore this further, we have carried out 2-D viscoelastic finite element modelling, which allows the analysis of the stress field both when the slab is driven by the slab pull only and when the plate convergence is included. We then analyze the stress changes within the subducted slab when a locked asperity is located on the thrust plane, and calculate the stress changes caused by the shear dislocation along the shallow angle thrust fault. We study the distribution of stress along vertical cross sections (perpendicularly to the trench), where the normal faulting events have been located.

SOURCE RADIATION SPECTRA IN SUBDUCTION AND SPREADING ZONES.

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Moment rate spectrum, as well as seismic moment Mo, corner period Tc, stress drop and P-wave energy Ep were determined for the earthquakes in spreading and subduction zones from teleseismic data. To correct the observed P-wave spectra for the energy loss along the wave path we used the AK135 Q-model as being in better agreement than PREM with the observations. A difference between the moment magnitude Mw and the energy magnitude Me (Yanovkaya et al, 1996) was used to discriminate between short- and long-period source radiation. Analysis of stress drops and Mw-Me indicates a difference in the radiation spectra in the spreading and subduction zones similar to that obtained previously by the analysis of the creepex (Kaverina et al., 1996). A relation between spectral parameters and focal mechanism is shown by analysis of some selected earthquakes at the Russian Far East and in Japan.

POSTSEISMIC TRANSIENCE & THE HETEROGENEOUS RHEOLOGY OF THE DEEP CRUST

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Observations of rapidly evolving postseismic deformation following major earthquakes are now retrieved with great accuracy and spatial coverage. Theoretical interpretation of this data, however, continue to be rather nonunique. One interpretation is that rapid deformations are caused by aseismic creep along the broken fault zone. An alternative interpretation is that deep and widespread flow of the lower crust and mantle is involved. The latter mechanisms are important since they act to relieve regional crustal stress. En toto, a consideration of quartz flow laws, thermal profiles, exposures of mylonitic horizons in geological cross section and the polymineralogy of the lower crust lends support to the hypothesis of widespread creep. A realistic model of the 1992 Landers earthquake in the southwestern U.S. is presented which is constrained by both GPS and laser strainmeter observations. The key feature of such a model is its ability to explain the multiplicity of exponential decay constants that are dictated by the data. For a heterogeneous viscoelastic model this multiplicity is due to the different flow laws that apply to spatially isolated pockets of "soft" material embedded within the crust and/or mantle. If the viscosity of isolated inclusions is approximately $3\text{–}4 \times 10^{15}$ Pa s then the observed 4 - 34 day, and longer, exponential decay time constants may be retrieved. The low viscosity inclusions in this model may have a concentration at, or lower than, 5%, depending upon the degree of anisotropy allowed.

THE ORIGIN OF COMPLEXITY IN SEISMIC SOURCES

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Earthquakes are very complex rupture phenomena as evidence by seismic radiation, aftershocks, variable slip distributions, etc. The origin of this complexity remains a subject of heated discussion. Some authors propose that slip heterogeneity and complexity are an essential part of the rupture process (Carlson and Langer, Cochard and Madariaga), others claim that heterogeneity must be quenched (physical discontinuities and material heterogeneity) because slip distribution on a preexisting fault is generally very smooth (Ben Zion, Rice, etc). I reexamine this question using an improved formulation of the BIE method for a flat 3D "acoustic" fault. In this model displacement is a scalar function that has a jump (slip) across the fault and stress a vector valued variable. We show that the integral equation has the same overall form as that of elastic shear faults, but it requires only a fraction of the storage space in the computer. This simplifies computations considerably so that we can simulate suites of "acoustic" earthquakes in 3D as we did earlier in 2D with Cochard. Results show that the behavior of this simple system is narrowly controlled by the friction law. I consider simple friction laws (slip and rate-weakening) and a simplified version of the state dependent friction of Dieterich and Ruina. We find that heterogeneity disappears if friction has very long memory effects, while it is strong if friction is strongly and rapidly velocity dependent.

THE SELF-ORGANIZATION OF THE CRACKS ARISING DURING LOADING THE ROCK AS THE REASON OF EARTHQUAKE

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The model of the crack self-organization arising in the rock sample (granite) during its loading is suggested. This model is based on the proposed effect of the acoustic wave interaction between the formed cracks. In this model the solutions of the Fokker-Planck equation are used which explain the results of laboratory's experiments in which the phenomenon of the spontaneous increase of the acoustic emission intensity, its spatial and temporal clasterization and the fractal structure formation in the presence of the constant and smoothly changing load on the rock samples.

EARTHQUAKE THERMODYNAMICS AND EARTHQUAKE SHEAR BAND MODEL

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Thermodynamic modelling of deformation processeses at the earthquake foci is presented. Our previous paper (Tectonophysics 277 (1997) 219-233) is extended and dimensions of the earthquake source were determined. Moreover, an entropy jump during an earthquake and seismic moment were expressed in terms of microscopic quantities. Fundamental thermodynamic relations for line defects (dislocations, linear vacancies) are formulated under the assumption that a dense network of defects forms a kind of superlattice. The superlattice is treated as a reference state. Thermodynamic functions of line defects are associated with defects in the superlattice. With this assumption the Gibbs free energy may have a minimum corresponding to the equilibrium concentration of vacant dislocations in the superlattice. A departure from the superlattice is investigated during deformation processes and fracturing. Some parameters of the earthquake source are determined and comparisons with seismic measurements are depicted. A good agreement with observations is confirmed.

TEMPORAL VARIATIONS IN SCALING RELATIONSHIPS OF A FLUID-CONTROLLED FAULT IN A SELF-ORGANIZED CRITICAL STATE

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An earthquake model that couples the mechanical effects of fluid with long-term plate motion self-organizes to a state where one final unbroken patch (asperity) remains along the fault plane. Following the failure of this final asperity at around 350 years, the model fault maintains a fully self-organized critical state, with additional asperities forming, destructing, and migrating along the fault plane. The self-organized critical state is evidenced by a power law spectrum ($1/f$ noise) of the seismicity timeline for the subsequent 800 years of model simulation. Because physical units are preserved in this model, scaling relationships can be compared directly with observations. I present the evolution and variations of scaling relationships among model parameters while in this critical state, including source dimension, seismic moment, and stress drop. Two scales emerge between source dimension and seismic moment. An L^2 scaling is observed which reflects isolated events and results from the initial assumption that slip is proportional to stress drop. A strong L^3 scaling also evolves, and which reflects the correlation of long-range interactions set up in the self-organization of the system. Two scaling clusters emerge between seismic moment and stress drop, with larger events having stress drops between 1-10MPa, and smaller seismic moments having stress drops between 10-100 MPa. This is also observed in two distinct clusters relating source dimension to stress drop. Throughout the simulation, the b-value stays relatively stable with a value of about 0.7, but spatial and temporal variations are observed corresponding to the slip behavior at depth.

A ROLE OF THE CONSTITUTIVE LAW IN SCALING SCALE-DEPENDENT PHYSICAL QUANTITIES INHERENT IN SHEAR RUPTURE

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It is widely recognized that some physical quantities inherent in shear rupture are scale-dependent. Such scale-dependent physical quantities include the shear fracture energy, the breakdown zone size and its duration, the nucleation zone size and its duration, the slip acceleration, and the cutoff frequency of the power spectral density of the slip acceleration versus time record. How can these scale-dependent physical quantities be treated unifyingly in quantitative terms ? The introduction of the constitutive law is indispensable for providing a unified comprehension for the shear rupture of any size scale - small scale in the laboratory to large scale in the Earth as an earthquake source, and the above question can be answered by formulating the constitutive law for shear rupture so as to meet the physical constraints, which lead to the conclusion that the constitutive law be formulated as a slip-dependent law. The slip-dependent constitutive formulation, which includes a scaling parameter D_c, allows one to treat scale-dependent physical quantities unifyingly in quantitative terms. D_c plays a fundamental role in scaling scale- dependent physical quantities, and D_c in turn is prescribed by the fault zone property, particularly by geometric structure of the fault zone.

NUMERICAL MODELLING OF FAULT INTERACTION USING THE 3D DISTINCT ELEMENT METHOD

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The current study deals with fault interaction modelling, using the 3D Distinct Element Method. This method allows numerical modelling of rock masses affected by natural discontinuities such as faults. The behaviour of the faults as induced by far field stresses is modelled. Rheological properties of the rocks as well as mechanical behaviour of faults by means of Mohr-Coulomb criteria is taken into account. According to some assumptions, it has already been demonstrated that fault displacements are responsible for local stress perturbations. However, the behaviour of conjugate fault patterns follows usual laws based on the Wallace-Bott hypothesis. Such models consider that faulting is directly related to the regional stress tensor. In actual cases of more complex patterns that includes inhereted planes they fail to explain some observed fault displacements. The aim of our study is to demonstrate, in the case of non-conjugate fault patterns made of two inhereted faults, that faults interact by means of local stress perturbations induced by their displacements. And fault displacements are led by the local stresses instead of being led by the regional far field stress tensor.

SLIP DISTRIBUTIONS AND SOURCE-TIME FUNCTIONS IN A HETEROGENEOUS SLIDER-BLOCK MODEL

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We consider a two-dimensional array of masses attached to a driver plate and coupled together by springs as a simple model of an earthquake fault. The blocks rest on a table and have a random distribution of static coefficients of friction, characterized by a coefficient of variation, to model geometrical irregularities of the fault zone. The coefficients of friction are also strain-rate dependent in a manner consistent with laboratory-derived friction laws. This model is integrated forward in time and analyzed with respect to many features including the frequency-size distribution of slip events, the frequency of the occurrence of foreshocks and aftershocks, the scaling of stress-drop with moment, and the statistics of slip patterns and far-field displacement functions. The model behavior is compared to observed seismicity in each respect. As the fault-plane heterogeneity is increased in real and model seismicity, the ratio of the largest event to the background seismicity decreases, richer foreshock and aftershock sequences are observed, and displacement functions are more highly variable in space and time. All of these features are quantitatively related to the fault-plane heterogeneity.

FAULT INTERACTION CAUSED BY ELASTIC (STATIC) AND VISCOELASTIC (POSTSEISMIC) STRESS CHANGES

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We study the stress field produced by a shear dislocation in a spherical, viscoelastic, stratified, self-gravitating earth. This model allows for a self-consistent investigation of coseismic and postseismic stress fields over distances ranging between few kilometers to thousands of kilometers, where plane geometry fails. Even if the spherical earth model provides an analytical solution for the stress field, it does not allow to easily obtain the stress tensor in the cartesian framework. Thus the computation of the Coulomb failure function in the spherical framework is not straightforward. For this reason we calculate the stress field by means of a numerical differentiation of ground displacements computed using the spherical method proposed by Piersanti et al. (1995). Postseismic relaxation should be taken into account to study the stress changes caused by an earthquake over time scales ranging between few years to several centuries. Thus, it has to be considered to investigate fault interaction between faults which ruptured during historical earthquakes. This is particularly important in regions where the tectonic load is low, because the long repeat times of large earthquakes requires the computation of both static and postseismic stress fields. In such cases, the static stress changes will also produce a larger time advance for earthquake failure. We applied our methodology to investigate the stress field perturbation in several italian seismic zones characterized by different tectonic regimes.

STRONG MOTION MODELLING FOR THE 1976 FRIULI EARTHQUAKE (NE ITALY)

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Strong ground motion accelerations for the May 6, 1976 Friuli earthquake (Ms=6.5) are computed for a spatially extended fault model. The position and geometry of the source model is in agreement with the most recent results concerning the relocation of the main shock and the new geotectonic evidences for the region under study.
The comparison of the synthetic accelerograms with the available real data constrains the feasible rupturing processes for this event and confirms its complexity. Different rupture models are considered also to estimate the range of the expected accelerations for possible future events in the area. Our results, besides contributing to a better knowledge of the 1976 earthquake itself, are of utmost importance for the seismic hazard assessment of the Friuli region.

MODELLING OF PRESEISMIC PROCESSES IN THE SYSTEM OF CRUSTAL BLOCKS.

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A model is proposed for slow movements of crustal blocks and for preseismic processes within fault zones. Crustal blocks are assumed to be rigid, and rheological properties of the material in the fault zones are described by a standard linear solid. Changes in the behaviour of the fault material due to microfracturing, water saturation of the cracks, increase of stresses prior to the rupture are modelled by changes of the parameters of the standard linear solid, which occur when strain or stress exceeds a given threshold. Displacements of the blocks, strains and stresses in the fault zones as functions of time are determined from a linear system of differential equations, which are solved numerically. Two 2D models are considered: movement in a vertical plane, which explains tilt anomalies prior to the earthquake, and movement in a horizontal plane simulating deformation anomalies obtained from geodetic survey.

SE11 Lithospheric dynamic processes as seen from geomorphology

Convener: Brun, J.-P.
Co-Convener: Kirby, M.

MORFOTECTONICS EVOLUTION OF THE NE BULGARIA

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The Neogene and Quaternary morfotectonic evolution the NE Bulgaria is a multi - phase process, connected to the global reorganization of the Precarpathian, Euxino - Caspian and Black Sea basins. It is manifested by tectonic predetermination of the alluvial basins, the stages in the development of the river and sea terraces, gravity - and Karst shapes as well as palaeoseismic efects.

EROSION AS THE MAIN MECHANISM OF UPLIFT ALONG TRANSFORM FAULTS

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The topography of transform plate boundaries is characterized by a narrow and elongated valley where is located the active transform fault. This valley is bounded at least on one side by an asymmetric ridge, with a steep slope towards the transform valley, and the gentle slope outwards. This topography is observed in all geodynamical settings: intracontinental, as along the Dead Sea rift, intra-oceanic (transverse ridges in fracture zones), or at the continent-ocean transition (marginal ridges in transform continental margins). In every case, the shape of the asymmetric ridge can be described by the upward flexure of the edge of a lithospheric elastic plate. Many hypothesis have been proposed to explain this flexure: extension perpendicular to the transform fault, differential thermal subsidence, lithospheric heating by thermal conduction across the transform fault. Here we present numerical experiments where flexural uplift is computed from unloading by erosion of the edge of an elastic plate. Because a transform plate boundary brings into contact lithospheric plates of different altitudes (because of differences in age, nature or thickness), the vertical transform fault accommodates at surface a step in topography. As a vertical surface can't be preserved, the edge of the higher plate is eroded. This erosional unloading is used to compute the flexural uplift for several natural examples, in different geodynamical settings. In most cases, erosion alone provides a good fit between the model and the shape of transform ridges.

VARIABLE WAVELENGTH TECTONIC PROCESSES IN PENINSULAR ITALY REVEALED BY A SYSTEMATIC RE-ASSESSMENT OF 125 KA MARINE TERRACE DATA.

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To investigate the role of tectonic uplift in the framework of modern Italian geodynamics we collected, interpreted and catalogued a large number of published studies on emergent marine terraces that were carved during the 125 ka sea-level highstand. Mapping of synchronous terrace surfaces over extended areas returns an accurate representation of the pattern of long-term vertical strain experienced since the time of terrace formation. The catalogue identifies and quantifies areas that have experienced uplift, subsidence and stability during the past 125 ka. The analysis shows that uplift and subsidence along peninsular Italy occur at various wavelengths, each of which provides information on the depth of the controlling tectonic process (upper crustal, crustal, lithospheric). Modern uplift matches the general topographic trend of the southern Apennines, suggesting that apparently distant occurrences such as the generation of relief, the crustal stretching and the extensional seismicity observed in the region, may have a common origin.

RIFT PATTERN AND ICE FLOW IN ICELAND DURING THE LAST GLACIATION

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During the last glaciation, the Icelandic rift was covered by a 1000-1500 m thick ice cap. The flow of the ice cap has been reconstructed from geomorphic features visible on the currently deglaciated ground and on SPOT images. The ice cap was drained by fast flowing ice streams whose location was controlled by geothermal anomalies associated with tectonic and volcanic activity. In these areas, subglacially erupted volcanic products have been removed from their eruption sites by the fast flowing ice and by subglacial debris flows triggered by volcanic eruptions. However, relics younger than 700 000 years have been preserved under ice divides and in areas sheltered from the ice flow by topographical accidents. In northern Iceland, subglacial volcanic relics crop out across a 90 km wide area, in comparison with the 50 km wide currently active Northern Volcanic Zone. In southern Iceland, heavily eroded subglacial volcanic edifices cover a currently inactive area located between the currently active Western (WVZ) and Eastern (EVZ) Volcanic Zones. The coincidence between the location of these edifices and the location of an ice stream in the reconstruction implies that, in addition to the WVZ and EVZ, volcanism and tectonics were also active in this area during the last glaciation. Because rift spreading for 700 000 years can account for a maximal 12 km widening, the discrepancy between the location of subglacial volcanic edifices and the location of the present-day tectonic and volcanic activity suggests either wandering or widening of the rift zone during glacial times, possibly due to the ice load on the lithosphere.

MORPHOLOGIC DATING OF SLOWLY EVOLVING SCARP USING A DIFFUSIVE ANALOGUE

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Absolute dating of scarps in a temperate climate environment poses problems related to the continuous vegetation cover. We present an alternate dating method based on the study of geomorphic characteristic of scarps. We assume here that the state of degradation reflects the time of scarp formation or its abandon. Two approaches were developed. The first assumes a model of scarp degradation based on a diffusive process (e.g. Hanks et al., 1984). The second, easier to implement, evaluates the state of scarp degradation using the slope distribution along a profile (Avouac, 1993). Our goal is to evaluate the applicability of these two methods for slowly evolving scarps in temperate climate environments. We show here that the second method necessites an age correction because it does not take into account the early stage during which the mid-height point is not yet affected by erosion. However this method reveals that several profiles have undergone a more complex evolution that cannot be identified with the first method. We apply both methods to a terrace riser located in the Rhine valley (eastern France) . We need a diffusivity value comprised between 0.3 and 0.9 m2/ky to model the very slow scarp shape evolution. We show that this cartographically continuous scarp is not necessarily isochrone : it presents segments of various ages, some of 35 ka, others of 15 ka. We also recognized on some profiles two distinct portions at 35 and 15 ka. We interpret this result as a reactivation by incision of a 35 ka old scarp, 15 ka ago.

SPECTRAL ANALYSIS OF TOPOGRAPHY IN EXTENSIONAL SETTINGS: INFERENCES ON THE QUATERNARY EXTENSIONAL TECTONICS OF THE APPENNINES (CENTRAL ITALY)

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A distinct characteristic of diffuse extensional processes is the regular spacing of crustal-scale tectonic structures. This has been interpreted as arising from the periodic instabilities of the upper crust undergoing stretching. This feature results in a dominant ~30 km wavelength controlling the topography. The analysis of topography in extensional settings is thus a powerful tool to study the relationships between morphology and lithospheric processes.

Active extensional processes in the Apennines are concentrated along the topographic ridge of the chain with a NE-SW regional direction of extension. The across strike width of the actively extending area and of the topographic ridge, is not constant along strike, being maximum (90 km) in the Central Apennines. In this area we study the relationship between topography and extensional tectonics by means of regional topographic cross-sections and 2D Fourier analysis. We interpret the presence of a NW-SE 30 km wavelength in the topography as the effect of upper crustal boudinage. Geophysical data show low Pwave velocity in the lower crust and thicker crust with respect to the surrounding extending area. This data suggest that a ductile lower crust permits the decoupling between upper crust and upper mantle, and that the boudinage is restricted to the areas with thicker crust and highest topography.

MODELING THE GEOMORPHIC RESPONSE TO TECTONISM

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A 2D coupled bedrock-alluvial channel evolution model is presented and forward modeling is carried out to ascertain the geomorphic response of the longitudinal profile of a river to a variety of tectonic forcings. In the bedrock portion of the channel the erosion rate is proportional to the local channel gradient and the discharge per unit width of channel, assumed to be proportional to the horizontal distance from the drainage divide. The sediment flux of the alluvial portion of the channel is proportional to the local channel gradient and discharge per unit width. The model has two free parameters, the coefficient of erodibility of the bedrock and the diffusivity of the alluvial portion of the channel. First we investigate the free decay of mean basin relief to instantaneous uplift. The decay is exponential, consistent with the classic parameterization of erosion as a function of relief, with a time constant dependent on the free parameters. We investigate the form of the longitudinal profile in response to different uplift histories and comparisons are made to real profiles. It is shown how the free parameters of the model can be inferred from the shapes of observed profiles.

Global geomorphology attests against mobilistic models.

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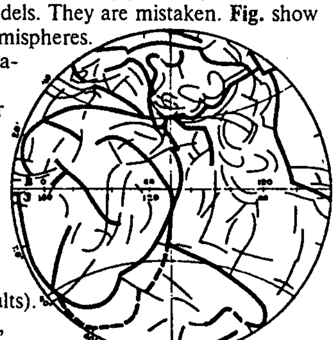
The dynamic processes of integral litosphera is chased in the global seems on different planetary degrees. The morpho-structural relief only is essential and adequate to sight the evidens of structural axial planetary symmetry. The Earth is strutured [1]. Reality must not be commuted by the mobilistic models. They are mistaken. **Fig.** show a simplified plan of the joint hemispheres. Their geotectonic seems are iterating one another. One can impose continent pictures of either earthen side. Complex zones of relief-1)Baltic seem and Britan oval, 2)Timan-Urals-Cambay graben-W.Indic have their real doubles: 1)Aleutian chain and Bowers arc; 2)Cordilleras-Californian bay-E.Pacific Rise (its southern decline is dubed by faults).



Ref: [1] Makarenko G.F (1997), Geoinformmark, issue 3, Moscow, 95 p.

THE EXPIRIENCE OF ESTIMATION OF GEOMORPHOLOGICAL SITUATION ON THE SHALLOWS, BASED ON THE ANALYSIS OF THE LAND GEOLOGY (SAKHALIN INSTANCE)

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In some cases structural elements of the land are traced on the bottoms of the seas. It is expressed by submarine linelly stretched rises, ranges-cuestas and some separate submarine rocks as well as sculptural-abrasion surfaces. Thus, it is possible to speak about genetic connection of the bottom relief and the land relief. It is true for the selfs, which are developed on the prolongation of the shells, platforms, plates and folded systems and inherited their structurally-geomorphological particulars. For the creation of the preliminary gemorphological image of bottom it is necessary to analyse the geological constraction and the tectonic conditions of territory. The last one exerts influence on the passing of the exogenous processes, in particular, on the sedimentation and creation of the conditions of abrasion and accumulation. On the whole, accumulative shores conform to the tectonically dropping coasts and abrasion shores conform to the rising coasts. Thus it is frequently possible to estimate the geomorphological situation on the bottom according to the nature of the shore. Such knoweleges help the explorer to drow the preliminary conclussions about the structure of the bottom before you begin the field reseach. It is, in particular, necessary for the working out of the actions for coastal fishery and for the economizing of labour, material and time resources. The geological map, the map of the newest tectonic, navigation maps, interpretation of the aerophotography and space pictures and litarary of some districts of Sakhalin have helped to solve the task of the preliminary estimation of geomorphology of Sakhalin island. Theoretical data is proved by the researches of SCUBA-divers which are taking place South-West Sakhalin and by hidroacustic side sonar survays.

HOLOCENE KINEMATICS OF THE FUCINO BASIN (CENTRAL APENNINES, ITALY)

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The Fucino Basin is a flat depression in the central Apennines. It is bounded by active faults, mostly normal but showing at places a slight strike-slip component of motion. Several of these faults were activated during the M_s = 7.0 earthquake of 1915. In order to better understand the kinematics of this region, we have carried out a detailed structural and morphological analysis of fault scarps around the Fucino Basin.
While the Magnola and the Tre Monti faults are very active, on the northern side of the basin, the faulting pattern is not as clear as on the eastern side of the basin. There, the Serrone, Parasano and Ventrino faults are arranged in a right-stepping fashion, suggesting left-lateral shear in a direction parallel to the system.
The right-lateral component of motion indicated by slickensides on all the three faults, and the offset of small streams across the Ventrino fault, suggests that the blocks bounded by these faults rotate counterclockwise, in a manner typical of "bookshelf" faulting. Given the values of slip-rate derived from the offset of post-glacial morphology, 0.5 to 1 mm/yr, the rotation rate in the east of the Fucino area is of 2-4 deg/Myr.

MORPHOTECTONIC EVOLUTION OF RIFTED MARGINS: NOT JUST FLANK UPLIFT AND ESCARPMENT RETREAT

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Escarpment retreat has traditionally been regarded as the dominant process in the geomorphic evolution of high-elevation rifted margins. Tectonic models that emphasise the role of syn-rift flank uplift have been coupled to the escarpment retreat hypothesis to provide a generic model for the morphotectonic evolution of rifted margins. Recent application of numerical surface process models has highlighted discrepancies between this generic model and the denudation history of specific rifted margins. We show modelling results for the eastern margin of South Africa and the southeastern margin of Australia and demonstrate that, in both cases, escarpment retreat plays only a minor role, the geomorphic history and structure of the margins is incompatible with simple flank uplift models, and the timing of uplift is unconstrained. Fission-track data from eastern South Africa are incompatible with an escarpment retreat model but indicate plateau degradation seaward of a pre-break up drainage divide. In south-eastern Australia, the drainage divide must also have been pre-existent and the escarpment formed at the locus of maximum isostatic rebound. The patterns of uplift recognised at both margins are most compatible with a magmatic underplating mechanism. Uplift at both margins is probably, but not definitely, pre-rifting.

RELIEF OF THE EARTH SURFACE, GEOID AND FOOT OF MANTLE: A COMPARISON

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1. Planetary relief has general antisymmetry of the Northern and Southern hemispheres: Laurasian continental massif and the South ocean; the Arctic ocean and Antarctica; the belt of great plains of the north and the belt of median-oceanic ridges of the South ocean. Planetary relief is correlated with geoid figure (uplift above spheroid in Southern hemisphere and depression in Northern one) and with Earth mantle structure which is more saturated by astenospheric layers in Southern hemisphere.

2. In relief of geoid and foot of mantle there are two segments: (1) segment of Western Pacific, Asia and the Indian ocean and (2) segment of Africa, Atlantic and America. Their inner structure is characterized by different groups of symmetry.

3. Ural-Oman-Madagascar slope of geopotential surface places on boundary of segments. Siberian and East-European cratons with marginal great escarps, alpine belts with high or low socle, the Arabian and Hindustanian subcontinents are symmetrically placed relatively the slope. Rejuvenated orogenic belts are placed eastwards of this boundary..

4. Region of Western Pacific where distortions of symmetry of planetary relief are summarized and the highest uplift of geoid surface places, engages the especial position in structure and geodynamics of the post-Gondwanaland Earth.

RELATIONSHIP OF SALT EVACUATION TO GROWTH FAULT DISPLACEMENT TRANSFER, GULF OF MEXICO

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The South Timbalier 54 oil field is located within a displacement transfer zone between oppositely-dipping growth faults in the Gulf of Mexico. Structure mapped with 3-D seismic data illustrate displacement transfer at various scales. At the field scale (~10 km), the transfer zone is spatially related to residual salt left on incompletely evacuated salt detachment surfaces. West and east of the transfer zone, growth faults sole into a salt weld. Toward the center of the zone, the faults lose throw and form a symmetric graben above a residual salt pillow. Miocene through Pleistocene interval isochrons illustrate the evolution of salt evacuation and transfer of growth from the north-dipping (counter regional) to the south-dipping fault system. Near the crest of the structure, displacement transfer occurs at a smaller scale (~1 km) between conjugate normal faults not linked to salt. Fault polarity rapidly changes in a narrow zone of penetrative strain.
Large portions of the shelf of the Gulf of Mexico were blanketed with tabular salt close to the Miocene seafloor. Plio-Pleistocene deltaic depocenters loaded and evacuated the salt down dip. Present-day shallow salt domes and deeper residual salt pillows above a Miocene salt weld represent the incomplete evacuation of salt. Many of these buried salt features are the locus of complex fault interactions at shallower levels and are associated with oil fields.

SE12 From the Arctic to the Mediterranean: salt, shale and igneous diapirs in and around Europe

Convener: Mart, Y.
Co-Convener: Vendeville, B.C.

THE EGERSUND-OGNA ANORTHOSITE MASSIF, SOUTH NORWAY : A FINITE ELEMENT MODELLING OF DIAPIRISM

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This work aims at testing the mechanical relevance of a petrological model of anorthosite massif diapiric emplacement. The Egersund-Ogna massif (S. Norway) is of particular interest because recent petrological and geochronological data constrain the initial geometry and the emplacement conditions and timing (about 2Myr). Based on these data, models made up of one brittle layer (upper granitic crust) and three viscous layers (lower part of the granitic crust, noritic lower crust and anorthosite) have been built up, considering an axisymmetric state of deformation. The brittle behaviour is represented by an elastoplastic modified Drucker-Prager law and the viscous ones by elastoviscoplastic laws with Newtonian viscosity. An inverse density gradient is considered between the lower crust (d=3.00) and the anorthosite (d=2.75), the loading consisting only in gravity. The modelling is carried out using the LAGAMINE large strain Lagrangian finite element code coupled with artificial passive markers and with an automatic re-meshing algorithm designed to deal with complex cases such as multi-domain geometries.
The results show that, from a mechanical point of view, the diapirism model is a consistent assumption for the emplacement of anorthosites because realistic diapir and rim-syncline shapes are obtained. Moreover, the numerically obtained emplacement timing (about 2.5Myr) is in agreement with the available geochronological data, and the computed strain field is coherent with the field measurements (Havenith et al., subm.), especially regarding the circumferential extension which becomes the largest extension strain component in the flattening phase.

EXTRUSION MECHANICS IN ACTIVE MUD VOLCANOES ON THE MEDITERRANEAN RIDGE

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Drilling two submarine mud domes situated in the Olimpi field on the northern flank of the Mediterranean Ridge accretionary complex has documented episodic eruptive activity over the last 1 to >1.5 million years. An evolution through extrusive building of a cone, followed by successive eruptions of clast-bearing mud debris flows and subsequent subsidence can be deduced for both domes. The mud breccias recovered are gas-rich and contain up to 65% of polymictic clasts. Results from permeability and shear strength tests, grain size analyses, sedimentary textures, and clast provenance provide clues concerning the mechanism of mud volcanism. The collision of Africa with Eurasia resulted in backthrusting of the evaporite-dominated accretionary wedge against a rigid backstop. This allowed egress of overpressured fluid-rich mud of presumed Messinian age from the décollement, although many of the clasts may have originated from the overlying accretionary wedge.

CENTRAL GRABEN SALT DIAPIR FIELDS, N. SEA: GEOMETRY AND STRUCTURAL EVOLUTION

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This study focusses on six diapirs in the Central Graben of the North Sea. Central Graben salt diapirs initiated in Triassic times as salt walls along extensional faults and evolved into diapirs in Jurassic times without going through a prolonged pillow phase, as there are no primary and secondary rim synclines observed. Diapiric growth was by downbuilding with a subtle relief maintained through the Cretaceous to late Tertiary period, with some diapirs periodically emergent Important unconformities are developed during the Middle Miocene with high-angle onlap seismic reflectors above the unconformity surface which indicate high relief on the diapir. This is interpreted to be produced by Alpine compression, which is recognised in the Central Graben for the first time. We will discuss criteria which can be used to identify diapirs rejuvenated during compression.

Two kilometres of core have been examined to characterise the deformation patterns in the overburden Palaeocene sandstones and Late Cretaceous chalk. Chalk deforms by pressure solution, with up to 50% of the material removed above the Machar diapir, and by extensional faulting and joint development which are intensively developed over the crest of the structures. The Palaeocene sandstones deform mainly by bedding-parallel slip along shale horizons and by pervasive grain flow and slumping when the sediments are close to the surface.

EVOLUTION OF THE KŁODAWA SALT DIAPIR, CENTRAL POLAND

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The Kłodawa salt diapir located within the Danish-Polish Trough in central Poland is about 6 km high, NW-SE trending structure composed of Zechstein evaporites. Tectonic structures preserved in it document 2 distinct stages in the diapir evolution, both related to extension at a crustal scale in the Danish-Polish Trough: (i) a stage of lateral migration of salt which was followed by (ii) a stage of vertical migration of salt.

During the first stage, multi-sets of sheath folds and décollement structures were developed in the bedded rocks. They occur in weakly strained parts of the diapir, where even horizons of undeformed desiccation polygons are present. Geometrical features of these structures indicate that they have formed due to gravity gliding towards the East, towards a quickly subsiding basin. This basin was a response of the pre-Permian basement to crustal extension. It was fault bounded and the western termination was located on the line of the present day diapir, as evidenced by highly increased thickness of early Mesozoic strata east of it. Gliding towards the basin led to thickening of evaporite sequence and, thus, to increase of a density contrast between the evaporites and the overlay. The stability of rock arrangement was lost in the Keuper and then the second stage of the diapir evolution started. During the stage of vertical migration of salt, dominantly rock salt beds started to move upwards due to their lowest density, thick accumulation and low competence. More competent portions of evaporites were passively carried as rafts within rock salt. The upward movement continued until the upper Cretaceous and it is evidenced by a new generation of sheath folds refolding the older ones. The movement initiated over the fault, i.e. in the zone of the highest extension of the overlay.

EVAPORITE DIAPIRS IN THE SOUTHERN MOESIAN PLATFORM AND ADJACENT ALPINE OROGEN (BULGARIA)

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Portions of two major tectonic units are located on the territory of Bulgaria: the Moesian Platform (southern part) and the Alpine north verging thrust belt (Balkan segment). Two thick anhydrite-salt successions: the Upper Permian and the Upper Triassic, are established in the transition zone between them. The origin and the development of the two evaporite basins are controlled by the Permian-Triassic rifting. Both were affected lately by diapirism, disparate in the platform margin and the frontal thrust zone.

The late Permian salt deposits are spread locally in the southern platform margin. They are mobilised in a very high salt dome (> 4,000 m), which has pierced all the overlying Mesozoic and Tertiary layers almost through the earth's surface. The dome has risen upward on several stages.

The Carnian evaporite deposits are widespread in the whole east Balkan north-leading thrust sheet (known as Forebalkan). They are mainly composed of anhydrite. The origin, the depositional thickness and the diapirism of the evaporites had been strongly controlled by a network of listric longitudinal faults and transverse normal or strike-slip faults. The diapiric ridges originated over normal faults in the carbonate basement. Later their development continued under the north-oriented compression, which caused the thrusting. The main detachment surface is linked to the base of the salt lenses or to the evaporite complex. In the most intensively thrust folded northernmost zone of the Forebalkan the altitude and complexity of the diapiric ridges increase.

GRANITES ARE NOT DIAPIRIC!

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There is growing consensus that granitic (s.l.) magmas rise through Earth's crust not as diapirs but in narrow dykes. The differences between these two competing end-member models are fundamental, and the implications are profound for our understanding of the tectonic and geochemical evolution of the continental crust.

All evidence strongly favours (fracture) dyke ascent for most granitic magmas. Reassessment of granitic magma viscosity and modelling shows that dyke ascent is both rapid and thermally efficient. Structural and petrological features expected in crust through which granitic diapirs have passed have not been discovered. Upper crustal granites commonly have forms and structures that preclude diapirism as the emplacement mechanism. In contrast, granitic dykes are common in exposed mid-crustal sections, suggesting ascent through fracture systems is the primary transport mechanism for granitic magmas.

TRIASSIC STRUCTURAL DISTRIBUTION OF THE ZECHSTEIN SALT IN SOUTHERN NORTH SEA AND CONSEQUENCES FOR FURTHER TECTONIC HISTORY

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In the Southern Norwegian North Sea the main tectonic event following the Zechstein salt deposition is the formation of a wide Triassic Basin. During this Triassic basement-involved extension the Zechstein salt clearly acted as a décollement level allowing the cover to deform by thin-skinned extension and form listric faults, tilted blocks, overburden rafts and buckle folds. The structural redistribution of the salt, including salt welds below rafts, salt pillows, walls, diapirs, and salt-cored anticlines was mostly acquired at this time.

Then the Southern Norwegian North Sea underwent multiple rift phases later overprinted by tectonic inversion. The fault trends and partitioning within the overburden will be strongly influenced by the salt distribution acquired during Triassic time. During the Jurassic/Cretaceous rifting phases, salt played a major role in decoupling the overburden from the normal-faulted basement. On the edges of the main basins, most faults formed above the crest of Triassic-age salt structure as they fell and subsided. From Cretaceous to Tertiary, several pulses of tectonic inversion squeezed and rejuvenated some diapirs. Local gravity gliding can also reactivated previous salt structures.

DIAPIR REJUVENATION BY CONTRACTION

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Contraction can exert an important control on diapir development. Salt diapirs are weak points in the sedimentary cover. During contraction, deformation is preferentially partitioned into the diapirs, squeezing the diapir stems and thus adding tectonic pressure to the natural buoyant pressure within the diapirs. The net effect is a rejuvenation of the diapirs; the cause of the deformation (i.e. contraction), however, often remains cryptic. In the absence of direct structural evidence for contraction (i.e. folds or thrust faults), contraction may be the cause of rejuvenation in cases where diapirs suddenly start to grow after a long period of immobility, or grow in short pulses interspersed with long periods of immobility. In this paper we will show examples from the Barents Sea, UK and Norwegian Central Graben, southern North Sea, and the Polish Trough, where diapirs show evidence of rejuvenation by contraction. The examples will illustrate a wide range of structural styles. All the salt-structures show characteristic pulsed growth histories where very thick roof-sections have been deformed, some developing large rafted-sections. The precise source of the contraction is, in all cases, cryptic; it may simply result from gravitational sliding.

IGNEOUS DIAPIRISM

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Following the analogue experiments of Grout and Ramberg in the 1950Æs and 1960Æs diapirism became the popular and accepted way of interpreting sub-circular plutons with concentric internal fabrics. In the 1970Æs and 80Æs diapirism was seriously questioned on two counts. Firstly actual measurement of the nature of the strain in these bodies showed were more likely to have inflated as balloons at the point of emplacement rather than have travelled up through the crust with this geometry. Secondly numerical analysis revealed that in the mid to upper crust plutons were arrested by premature crystallisation as they advected heat to the wall rocks in an attempt to continually reduce the wall rock viscosity. Recent models, which attribute to the wall rocks power law rheologies, have attempted to reinstate diapirism as a major process. The alternative school that has developed is that granites ascend through the crust in dykes rather which then feed sites of emplacement at higher levels. The emplacement sites both for dyking and for diapirs may be determined structurally and tectonically. Emplacement/ ascent along active fault systems, either in transcurrent, extensional or thrust structures has been invoked in numerous studies and many plutons are clearly sited at the intersections of non-parallel fault and shear zone systems: invoking the idea of vertical conduits. At higher levels in the crust laccolithic inflation of dyke-fed plutons by upward deflection of strata is a popular model. Most recently numerical modelling of diapirism shows that their internal fabrics and petrographic patterns evolve because of shear- induced convection in the body. To date only one pluton in the world has had such patterns identified within it. These models and ideas will be illustrated mainly with examples from Europe.

QUANTITATIVE APPROACH TO THE EXTRUSION DYNAMICS OF ACTIVE MUD VOLCANOES ON THE MEDITERRANEAN RIDGE

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Based on modifications of Stokes' and Poiseuille's laws, mud extrusion rates have been estimated for mud volcanoes on the Mediterranean Ridge accretionary complex. Mud ascent velocities are found comparable to those of silicate magmas. Using physical property, structural and flux data of the mud breccias, and compiled data from mud domes on land, the diameter of the feeder channel as well as the depth of origin for the overpressured muds have been estimated for the first time. Feeder channels of decimeters to a few meters in diameter (depending on the controlling parameters chosen) are narrower than previously assumed. Gas efflux estimates constrain a source depth close to the base of the mud cones in the Olimpi field. Thus, the efflux data suggest that the overpressured muds were not mobilised at décollement depth, as estimated from the thermal maturity of solid organic carbon in the mud breccias. A comparison of mud efflux rates and the total volumes of mud extruded shows that only a fraction of the time span constrained from biostratigraphic data (c. 1 Ma) is needed to build up the Milano and Napoli mud domes. Mud volcanism here is, therefore, a highly episodic phenomenon.

THE RECENT STRUCTURE AND MUD DIAPIRS OF THE SOUTH-EAST OF CRIMEA'S CONTINENTAL MARGIN.

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Geological-geophysical investigations carried out during the 6th cruise of the R/V "Gelendzihk" within the Training-through-Research Programme ("Floating University") gave possibility to view the structure of the recent submerged margin off the SE Crimea from a new standpoint. Firstly, the recent submarine relief of the Crimean margin is characterized by many small and narrow canyons. These canyons are located on the upper continental slope and are 10-20 km long. As a rule, the canyons cut through Quaternary sediments and sometimes older rocks down to the Miocene. Secondary, the modern structure resulted from neotectonic movements, having preferentially horizontal direction due to the influence of the mud diapirism and volcanism. Thirdly, the most favorable conditions for the development of mud volcanism (particularly for the formation real volcano cones) are observed in the deepwater part of the investigation region. All of the studied volcanoes, which rise more than 50 m above the surrounding seafloor, are located at a waterdepth of 1700 to 2000 m.

DIAPIRISM AND NEOTECTONIC ACTIVITY IN THE SOUTHEASTERN MEDITERRANEAN

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Numerous elongated salt diapirs crop out in the SE Mediterranean, showing positive relief in some places and dissolution depressions in others. Some of the diapirs offset the uppermost sediments, so that their emplacement is recent. The SE Mediterranean is a zone of tectonic collision between Africa and Eurasia, and the co-occurrence of diapirism and tectonic compression requires elaboration. Evidence for post-Miocene subsidence in the SE Mediterranean basin was recently encountered by ODP leg 160 on Eratosthenes Seamount, which is being thrust under Cyprus. The tectonic model suggests that the Plio-Quaternary thrust faulting, affected large parts of the SE Mediterranean Basin, but distal segments of the footwall were uplifted. This uplift caused local extension, which enhanced diapirism.

MUD AND EVAPORITE DEFORMATIONS FROM THE EASTERN MEDITERRANEAN SEA: EVIDENCES FROM THE PRISMED II CRUISE (RV ATALANTE)

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During the Prismed II cruise of the RV Atalante (Feb 98), several areas of the Levantine basin, where diapiric structures have already been partly explored, have been surveyed in detail using continuous swath mapping system, acoustic imaging and seimic reflection profiling available on the research vessel One of the scope was to better understand their significance in a general structural convergent setting.
We present here the preliminary interpretations concerning three main areas where either mud diapirs and volcanoes or messinian evaporite diapirs have been mapped in details.
We intend first to relate mud volcanic and diapiric features known in the Central Mediterranean Ridge to compressive or/and transcurrent tectonics presently active in the area as a consequence of the convergence and incipient collision between Africa and Aegea. We then review the diapiric deformations detected around the Florence rise and South of Cyprus Arc to tentatively better assess their nature and origin. Finally we illustrate the progressive transition between halokinetic deformations, detected near the base of the Nile deep sea fan, and tectonic-related features that characterize the Eastern branch of the Mediterranean Ridge

EXAMPLES OF EXTENSIONAL AND COMPRESSIONAL RIFT-RAFT TECTONICS FROM THE ZECHSTEIN EVAPORITIC BASINS OF NORTHWEST EUROPE.

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Regional mapping of the Central North Sea and East Irish Sea and comparison to structural styles observed in the Southern North Sea illustrates that gravitational gliding above a salt substrate is a common geological process. A once continuous sheet of Ėbrittleı Triassic sediments above a detachment surface of Zechstein salt has been fragmented by a combination of upslope extension and consequent downslope compression. Associated halokinesis is primarily controlled by regional tectonism and salt thickness. This process if referred to by Amoco (UK) as Rift-Raft Tectonics. Variation in geological forms are described and empirically related to tectonic environment as a result of the interplay of the controls identified. These include salt thickness, lithology of the Mesozoic overburden and regional gradient. Physical and finite element modelling has been used to demonstrate the validity of the interpretation and thus demonstrate the importance of gravitational gliding in forming structures in salt basins.

STRUCTURE AND EVOLUTION OF SALT IN THE NORTHEAST GERMAN BASIN -- CONCLUSIONS FROM 3D MODELLING.

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We analysed the structure and subsidence history of the Northeast German Basin using a 3D model. The basin contains about 8 km of Permian to Cenozoic sediments including the Upper Permian Zechstein-salt that plays a major role for present-day structural setting. One of the main characteristics of the basin is a vertical tectonic zonation. A pre-Zechstein succession, which lacks significant internal structures, is decoupled by the thick Zechstein salt-layer from a strongly deformed post-Zechstein succession. Intensity of salt mobilisation varies within the basin indicating variations in strength of the underlying basement. In the south-eastern part of the basin numerous salt structures piercing and bending their cover layers are aligned along NNE and WNW trending axes. In contrast, salt mobilisation is minor in the north-eastern part although we have to assume highest initial salt thickness there. The base Zechstein horizon, imaged as a distinct flat reflector in seismic sections generally has no fault-related vertical displacements.
In addition to analysis of the present-day structure we calculate paleogeographic scenarios using a 3D backstripping method. This approach combines pressure dependent viscous salt flow with isostatic calculations. The results show that the main phase of salt mobilisation was Late to Post-Cretaceous in age. Thereby, salt obviously had a decisive influence as a strain distributor due to its ductile rheology, decoupling its basement from its cover.

SUPERIMPOSED SALT TECTONICS IN THE DUTCH SOUTHERN NORTH SEA: FROM GRAVITY GLIDING TO GRAVITY SPREADING.

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The Southern North Sea has undergone several phases of extension from Mid Triassic to Late Jurassic followed by phases of inversion from Latest Jurassic to Paleogene. The interplay between successive regional deformation phases, an important Paleozoic structural heritage and the presence of several decollement layers, including the thick and mobile Zechstein salt, resulted in complex structural styles.

The understanding of the origin and evolution of salt-ridges and associated structures at both local and regional scales (3D, 2D seismic and regional maps) allowed the definition of small-scale gravity tectonic systems linked to the subsidence and inversion of basement grabens. Subsidence of the Sole Pit Half-Graben produced SW-verging gravity gliding buckle-folds while that of the Central Graben induced listric faults and reactive diapirs away on the margins (Step Graben and Schill Grund High). Inversion caused gravity spreading above the salt : for Sole Pit Half-Graben a NE propagating trend of folds on Cleaver Bank High and for the Central Graben squeezed diapirs to the West and thrust faulting to the East.

This is described by a sketch cross-section from the Central Graben to the Sole Pit Trough

Dynamic sequence stratigraphic prediction and thin-skinned extension: Examples from the Varg Trend, Norwegian North Sea

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The Varg Trend lies on the Sleipner Terrace in the eastern Viking Graben, Norwegian North Sea. Regional polyphase extensional tectonics in the Permian, Triassic and Upper Jurassic created a complex structural setting that controlled the distribution and preservation of Oxfordian reservoirs. Thin-skinned extension, gravity gliding, forced folding and diapir collapse produced extreme variation in the accommodation space available for deposition of the Upper Jurassic reservoirs, in addition to controlling depositional pathways and facies belt development. Basement extension (Callovian - late Oxfordian) promoted diapir collapse and forced folding, creating a N-S trending play fairway. Additional accommodation space was created by the gliding and rotation of Triassic pods over an eastwards tilted basement. Further basement faulting in the mid-Volgian resulted in renewed pod rotation and grounding, and local reactive diapirism. A fully integrated approach utilising seismic interpretation, dipmeter data, wireline-log sequence stratigraphy, and experimental tectonic modelling allows a predictive seismic and sequence stratigraphic framework for the Upper Jurassic section in the Varg trend to be established.

NEOGENE STRIKE-SLIP FAULTING AND PLUTON EMPLACEMENT IN SOUTHERN TUSCANY (ITALY).

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The Neogenic extensional collapse of the inner sector of the Northern Apennine orogenic wedge was accompanied by emplacement of chiefly anatectic plutonic associations, Late Miocene to Middle Pleistocene in age. In the Northern Tyrrhenian Sea region, eastward-dipping extensional shear zones drove emplacement of the monzogranitic intrusions of Elba (7-5 Ma), Monte Cristo (7Ma), and Giglio (5Ma) islands. Our interest focused on the coeval acidic stocks of Gavorrano (4.9 Ma) and Campiglia Marittima (5.7 Ma), located along the Southern Tuscany coast. Geological, structural and petrographical data have been collected in order to characterize their emplacement mechanism. N-S right-lateral strike-slip tectonics has been recognised as the main deformation event in the studied area. Strike-slip fault segments have been recognized as being active during and after the late stage of emplacement of both plutons, controlling their rise in correspondence of releasing bands. The collected data at Campiglia and Gavorrano, together with the previously collected data in the Northern Tyrrhenian Sea, permit to interpret the N-S, Late Miocene-Pliocenic strike-slip faulting as a secondary feature in a context of generalized post-orogenic extension. In this framework, strike-slip segments would be active in the brittle domain locally accomodating the eastward-asymmetric ductile extensional shear at depth. Thus, their role possibly consisted in localizing the rise of crustal melts produced during the post-orogenic thermal relaxation processes which followed crustal thickening.

NEW DATA FROM THE DIAPIRISM TYPE AREA – EAST CARPATHIANS BEND.

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The salt diapirism phenomenon was firstly described in 1907 by Mrazec in the East Carpathians Bend Zone. In this area, the salt formation (massive salt bodies associated or not with sedimentary breccias) accumulated at two different stratigraphic levels: Early Miocene (Burdigalian) and Middle Miocene (Badenian).The Early Miocene salt diapirs developed along four liniaments, each of them being in a different stage of evolution, as follows, from north to south: overturned, exaggerated, attenuated and cryptodiapirs. All these types of diapiric folds have been traversed by at least one seismic line, recorded in different years. The seismic lines shown on the poster will demonstrate the appearance of the diapirs as well as the structure above and below and in the adjacent synclines. Most of the halokinetic structures are well controlled by wells and consequently the interpretation on the displays is a complex one. The overhead diapirs are characterized by a southwards vergency of the salt body, that sometimes thrust over the outer external compartment. The exaggerated diapirs have steep, more or less vertical walls and in places the salt core has been completely squeezed. The attenuated diapirs have pierced, but not completely, their hanging wall. The cryptodiapirs show a lens like shape, practically without important detachment along their limbs.

THE EFFECT OF RISING MANTLE DIAPIRS ON FORMATION AND EVOLUTION OF TOPOGRAPHIC RELIEF

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We combined various geological and geophysical data to design and constrain mechanical-mathematical models at the scale of the lithosphere to investigate the structural influence of deep-seated mantle diapirs onto the Earth's surface. Models varied the rheological properties and the boundary conditions. Model solutions were calculated both analytically and numerically. Results indicate that deep-seated and slowly rising mantle diapirs cause formation of structural and topographic depressions on the Earth's surface. Stretching in layers can be not great. By contrast, if the mantle diapirs are shallow or if they rise fast, a topographic high formed above the diapir. Using analytical models, it is possible to determine which parameters are critical in controlling the influence of the shape, depth and rise rate of mantle diapirs onto their topographic expression. Conversely, we can use topographic, geothermal, and/or gravity data to infer the geometry, depth, and rise rate of deep-seated mantle upwelling in the asthenosphere. We will compare our modelling results with structural examples from the Pre-Caspian Depression and from the Alps.

RATES OF SALT EXTRUSION IN THE ZAGROS

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Ten of the diapirs of Hormuz salt extruding along strike-slip faults in the Zagros are being monitored at yearly intervals with the help of the Geological Survey of Iran. Five extrude faster than they dissolve. Salt velocities vary yearly but reach c. 4 m a^{-1} on the lips of summit domes. Numerical modelling of one implies that the salt has been rising out of its orifice at 1 to 2 m a^{-1} for 56,000 years despite being dissolved at a vertical rate of c. 2 mm a^{-1}. Such fugures suggests that a single cycle of extrusiion could pinch the local source and be complete after c.1 Ma.
Backstripping may therefore give a misleading impression where the geological control requires averaging past salt velocities over intervals longer than 1 Ma. The maximumsalt velocity of salt reported in a particular German diapir, of 0.125 mm a^{-1} during Cenomanian-Late Paleocene times, was averaged over 39 Ma and may include a brief interval when the salt there flowed c. 4 orders of magnitude faster.
The fastest horizontal displacement rate measured for salt in the Zagros, of c. 1.3 m/month, was toward steep river cliffs being carved into a mature salt extrusion. This 400 m deep valley could potentially close in c.100 years and trap river gravels in an asymmetric slot. Such a slot occurs beneath a zone in which the cap rocks were removed in a subgalcial ersoion channel across the German diapir for which the reported Miocene-Quaternary rise rate of 0.03 mm a^{-1} was averaged over c.23 Ma.

Tectonics vs. Buoyancy as the Drive for active diapiric growth

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NW Germany and the North Sea have provided the classic textbook examples used to define the concept of active salt diapirism (e.g., Trusheim, 1940). According to this definition, active diapirs rise buoyantly by forcefully lifting and deforming thick overburden roofs. However, combined geological, geometrical, and mechanical consi-derations suggest that most salt diapirs in NW Europe that underwent late active growth were not driven by buoyancy. Instead, there is ample evidence that local or regional compressional tectonics occurring after depletion of the source layer rejuvenated older, dormant diapirs. The clues for a tectonic, rather than buoyant, origin for such diapirs include (1) a thick, deformed roof above the diapir crest, (2) a pinched-off diapir stem, (3) a diapir crest located above the regional datum with strata in the adjacent depocenters remaining at the regional datum, (4) episodic diapir growth by brief pulses separated by longer periods of immobility, (5) diapir growth following formation of a secondary rim syncline, and (6) folds or reverse faults along strike.

ARGUMENTS AGAINST DIAPIRIC EMPLACEMENT OF GRANITIC PLUTONS IN THE BRITTLE UPPER CRUST

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Correlation between gravity data inversion and magmatic structures reveal that the organization of granitic plutons varies with the tectonic regime under which magma was generated. Deformation controls the whole cycle of granite formation. During melt segregation, the viscosity contrast between the liquid and its matrix induces strain partitioning that facilitates liquid flow. Ascent may be diapiric in the lower ductile crust if the matrix moves fast enough to accommodate magma displacement. This is valid only for magmas that remain in the lower crust, such as anorthosite. It cannot apply to intrusions into the upper brittle crust. The strength of the continental crust at the brittle/ductile transition is about 200-600 MPa, depending on whether normal or reverse faults are generated, and also on the thermal regime of the crust. It is at least one order of magnitude larger than the buoyancy forces, which are of the order 4-6 MPa/km of the granitic magma column. Thus, magma cannot intrude the brittle upper crust only by its internal forces. It requires additional forces to initiate fractures at the base of the brittle crust. In addition, the occurrence of negative gravity anomalies over granitic plutons rules out felsic magma stopping at a neutral buoyancy level.

QUANTITATIVE MODELLING OF THE EVOLUTION OF SALT STRUCTURES IN THE PRE-CASPIAN BASIN, RUSSIA

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The Pre-Caspian basin is a unique geological setting which includes many types of salt structures. The salt domes of the basin occupy a space of about 600,000 km^2 where the thickness of salt ranges up to about 5 km. There are more than 1,500 salt structures in the basin, among which are gigantic salt domes having an area of 6,000 km^2 and a height up to 10 km. Various stages of evolution are observed among these structures: initial (salt-pillow), mature (salt domes), and final (salt diapirs) which have obviously extruded at various time intervals. On the basis of the vast local knowledge of the regional geology and geophysics, we classify the salt structures of the basin by their genesis and shape. We study numerical models of the evolution of the salt structures to locate each sedimentary layer in geological time. To develop the models, we combine the Galerkin FEM allowing to compute a backward flow of salt and backstripping technique generally used in subsidence analysis.

SE13 Intraplate earthquakes, stresses and large scale tectonic structure

Convener: Gregersen, S.
Co-Convener: Panza, G.F.

EARTHQUAKE DISTRIBUTION AND REGIONAL TECTONIC STRUCTURE IN VRANCEA ZONE - ROMANIA

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This paper focus the attention on Vrancea zone and the surrounding area, because this is the most active and intense seismogenic area. Here are situated the most numerous, strongest and still unforeseeable earthquakes from Romania.
There were represented all the earthquake hypocenters from the period 1982 - 1996 situated in an area which includes Vrancea zone (25° - 28.5° E, 44.5° - 47° N) Because of the great number, they were found to describe well the limits of the tectonic plate (plate fragment ?) which is supposed to be subducted in this region until 200 km depth. These limits were put in direct relations with the known geology and tectonics of the area.
Available fault plane solutions for the crustal earthquakes are analyzed in correlation with the main faults of the area.
A model of the crustal structure of this region was derived on the basis of seismological data and linked with fault system in the area as it was established from geological and geophysical researches.

A tomography mapping of the plate sutures and intraplate tectonic within the European mantle

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The 3-D *P*-velocity distribution within the mantle beneath Europe and flanked terranes to 850 km depth and more be examined. As initial data exploited the set of first-arrival times of *P*-waves from strong earthquakes and explosions. A new traveltime tomography method proposed by V. Geyko for data recovering be employed. The following solid mantle properties of the explored terrane have been explained. Into velocity inhomogeneity's images bright not only all the large tectonic assembly: the Precambrian, Palaeozoic, Mesozoic, Alpine and oceanic structures but also locates and traces sutures and boundaries between great structures. Within zones flanking to sutures and boundaries immediately observes usual anomalous velocity varying that reflects effect of the smoothness, diffusing of the contact region stipulated by coupling, interacting and collision of the associated structures. The most important Teisseyer-Tornquist zone observes distinctively in Poland, the southern part of Jutland and the western margin Scandinavia and traces clear to the Faeroes Islands. Diffusing of the contact zone well observes under the western flank of EEP. Separated great tectonic structures, belts and assemblies tectonic structures imaging as unit at the same time can distinguish motley heterogeneous inner pattern. One of the well expressed they are the Alpine orogens belt where the Mediterranean, South and Central European, Anatolian, Caucasus-Iranian segments mapping differ sharply from each other. In turn specially two firsts characterise exclusively not uniform own structure.

CHANGE OF STRESS SINCE THE ICE AGE IN SCANDINAVIA

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In a small, northern part of Scandinavia, where the present earthquake activity is not significantly different from its surroundings, **large surface faults have been noted.** And these are interpreted to show the **occurrence of large earthquakes about 10.000 years ago.** Signs of this are coincident landslides as well as liquefaction in loose sediments, which are very well dated through varv-counting. Many Scandinavian scientists interpret the cause to be the deglaciation after the last Ice Age. And since the present dominating stress field in the area follows the pattern of the World Stress Map Project, namely compression within the plate, oriented in the direction of the absolute plate motion, the glacier off-loading is a significantly different cause 10,000 years ago. **Change of stress is clearly indicated.** Recently very detailed maps of deep-reaching faults in the area around Denmark has been compiled, and an obvious comparison was attempted. **Can we now point to some of these faults and call them active? Can the modern regional earthquake geography be well correlated with the mapped deep faults?** And the answer was for part of the region yes, while for another part it was NO. The region is full of known faults. Can we feel rather safe because the stress seems to have diminished since the end of the Ice Age 10,000 years ago? Or can we expect the 10,000 year earthquake one of these days?

NEW SEISMICITY AND FOCAL MECHANISM STRESS DATA FROM RANAFJORD, NORTHERN NORWAY

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A six-station seismic network in the Rana area, Northern Norway, has been in operation as part of the NEONOR (Neotectonics in Norway) project since 1 July 1997, with the primary purpose to monitor seismic activity along the potential postglacial Båsmoen fault. This area is the presumed location of the largest recorded earthquake in Northern Scandinavia, the M_S 5.8-6.2 event of 31 August 1819. Data from a Norwegian national seismic station in the region, made available by the University of Bergen, are used whenever possible to aid in the locations. The network currently records and locates around 30 local seismic events within the network each month, with magnitudes mainly in the M_L 0.5 - 1.5 range. The hypocenters are generally shallow (4-12 km), similar to other observed onshore seismic activity in the region (Meløy, Steigen). Focal mechanism solutions are determined by composites of first-motion polarities for clusters of events, or a combination of first-motion polarities and waveform modelling for larger single events. These focal mechanisms generally show a large, up to 90°, rotation of the direction of maximum horizontal compressive stress within the seismically active areas of the network, with regard to the regional (Fennoscandian) stress field. This suggests that more local sources of stress are more important, as compared to the plate motion related ridge push force in the regional case.

GETEROGENEITY OF THE INTRAPLATE AREAS AND SEISMICITY

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The complex typification of the Earth's crust, reflecting its modern state and structure, allows to determine the important features of the recent structure of the Earth's crust, including the manifestation of seismicity. This is especially actual for the intraplate regions where the regularities of the seismic process are not easy to be discovered. The processing data was performed applying the computer procedure of the cluster analysis which permits to produce the typification of any generalization degree. In this way obtained typification is "mobile" and different degree of its generalization shows that modern inhomogeneity of the Eath's crust within large tectonic units of the intraplate areaas is greatly varied. Some of them remain to be indivisible by any degree of breaking up into the separate types of the Earth's crust. On the contrary, other tectonic units, mainly depressions, turn out to be divided into complicated mozaic of the small blocks, formed by various types of the Earth's crust. It is important that observed and predicted seismicity within intraplate areas are connected to namely geterogenic depression zones. It may be suggested that different modern stablity of the large tectonic units reflects certain subtle "invisible" geodynamic processes which are also responsible for seismic manifestation.

NUMERICAL MODELLING OF SLAB DYNAMICS BENEATH THE VRANCEA REGION, ROMANIA

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The earthquake prone Vrancea region is situated at the bend of the Eastern Carpathians and control the seismicity of Central and Eastern Europe. We examine numerical models of block structure dynamics beneath this region by using results of geodynamic modelling of mantle flows induced by sinking relic slab. In the model of block dynamics the region is represented by a system of absolutely rigid blocks divided by infinitely thin plane faults. The blocks interact between themselves and with the surrounding medium. As the blocks are rigid, all deformation occurs in the fault zones and at interfaces separating the blocks and the surrounding medium. When the critical stress level is exceeded in some part of a fault plane, the stress drops, resulting in failures on other parts of the fault plane. The failures produce earthquakes. As a result of the numerical simulation a synthetic earthquake catalog is produced. The distribution of earthquake hypocenters in the synthetic catalog is in good agreement with that in the real catalog. Small variations in angles of slab rotation control the pattern of seismic release.

IMAGING AN INTRAPLATE ZONE OF SEISMICITY: THE BLYTHEVILLE ARCH IN THE NEW MADRID SEISMIC ZONE.

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The New Madrid seismic zone is one of the most important areas of intraplate seismicity and the most seismically active region in the Central United States. Seismicity in this area is shallow (4-15km) and consistent with a ENE-WSW compression. Earthquakes broadly occur along linear trends that outline the scars of a late Proterozoic graben, the Reelfoot rift. One of the most linear trends of seismicity coincides with the Blytheville arch, within the axis of the Reelfoot rift. Across the Blytheville arch near vertical seismic reflected energy significantly decreases and refracted energy is attenuated.

We have studied P- and S-waves recorded by the U.S. Geological Survey in 1991, along two 70-km long orthogonal seismic refraction lines crosscutting the Blytheville arch. We found that the Vp/Vs ratios vary laterally as a result of juxtaposition of sedimentary rocks having different elastic properties. Within the seismic zone, we found high Vp/Vs ratios that we have interpreted indicating the presence of fluids. Fluids filling fractures in the upper crust and tectonism make the Blytheville arch a zone of weakness, that is more prone to seismic rupture than the surrounding Reelfoot rift.

THE NEW RELEASE OF THE WORLD STRESS MAP

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The World Stress Map (WSM) is a global database containing information on the contemporary tectonic stress in the earth's crust. Information is derived from six types of stress indicators, namely earthquake focal mechanisms, well bore breakouts, hydraulic fracturing and overcoring measurements, and young (Quaternary) geological indicators like fault slip data and volcanic alignments. The new release of the WSM is published and described on the WWW page http://www-gpi.physik.uni-karlsruhe.de/pub/wsm. Among other things the web pages comprise information on the database structure and numerous maps showing regional subsets of the WSM database. Tectonic stresses and internal plate deformations are caused primarily by plate boundary forces, which are responsible for the movement of the lithospheric plates. These forces include ridge push at the mid-ocean ridges, basal shear stresses acting at the base of the lithospheric plates, and slab pull and trench suction forces at subduction zones. In addition to plate boundary forces, secondary stress sources can be superimposed, leading to local deviations in stress patterns. Examples of these secondary sources are flexural stresses from lithospheric bending produced by vertical loading of the lithosphere by islands or glaciation, unloading by deglaciation, or bending in subduction zones. Other important secondary stress sources are associated with lateral density contrasts as they occur at passive continental margins.

GEODETIC INVESTIGATIONS ON RECENT CRUSTAL DEFORMATIONS IN THE SEISMOACTIVE ZONE OF SAXON VOGTLAND

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A considerable seismicity is one of the remarkable features of the region Vogtland / Western Bohemia in Central Europe. The stress reduction takes place in a very special kind of seismicity - the swarms of earthquakes. During the last three years repeated GPS observations were carried out in a precise geodetic network. The GPS data were analysed, adjustet freely and intercompared with an older triangulation network applying a four parameter similarity transformation. The result contains informations about recent crustal deformations. The observation material allows the derivation of the horizontal components of local strain tensors from discrete points of the earth surface only. It represents a first geodetic approach to the description of a local stress and strain field. We attempt to match these informations to the tectonic structure of the area.

SE14 Modern rifts: plumes, kinematic conditions and lithospheric inhomogeneities

Convener: Deverchere, J.
Co-Convener: Achauer, U.

Sponsorship: Geosciences Azur UMR 6526, Univ. Pierre et Marie Curie, Villefranche-sur-Mer, France (GEOAZUR); Ecole et Observatoire des Sciences de la Terre, CNRS EP-533, Strasbourg, France (EOST Strasbourg)

SEISMIC TOMOGRAPHY AND CONTINENTAL RIFTS: A REVIEW

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Within the last decade many seismic tomography experiments covering some of the most prominent continental rift structures, such as East Africa (Kenya rift), ECRIS (Rhinegraben and Limagne/Massif Central), Rio Grande and Lake Baikal, have been carried out. These studies provided us very complex, each time quite different pictures of the lithosphere-asthenosphere system beneath continental rifts and demonstrated the necessity of high-resolution seismic tomography experiments when trying to connect the tectonic surface expressions with the mantle heterogeneities in understanding the tectonic evolution of each particular rift zone.

In this paper we shall review the results of seismic tomography experiments when applied to continental rifts. We will show the weakness of teleseismic tomography in resolving crustal structures and hence discuss the merits of the joint interpretation of seismic tomography data, gravity modelling and petrological data in the light of the shallow and the deeper structure of the rifts and their geodynamic evolution. In particular, we will argue, that in most cases the tectonic appearance of a rift is governed by a mixture of inherited structures, the regional stress field and the existance of a plume source.

TRANSITION FROM BAIKAL RIFT TO ALTAI-SAYAN TRANSPRESSIONAL SETTINGS IN EAST-CENTRAL ASIA

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The East Sayan massif is located in the transitional zone between the Baikal Rift System and the Altai-Sayan belt. The Present-day stress field changes rapidly from extensional in the Baikal Rift to transtensional in East Sayan and transpressional in Altai. SHmax direction remains relatively stable. The fault kinematics and stress field in Altai-Sayan is far from uniform. The tectonic regimes change quickly from strike-slip or compressional to extensional, depending on local conditions, as can be expected in transpressional-transtensional settings. The SHmax direction is also significantly reoriented in South-West Altai. The major controlling factors for this stress field fluctuation might be the reactivation of older structures, block interactions, crustal effects, and kinematic partition. Major differences between Baikal and Altai-Sayan provinces are also observed during the Late Cenozoic evolution. In both areas, a major reorganization of stress field and fault kinematics occurred in the Late Pliocene. The transition between the two provinces is best expressed in the Tunka depression. This parallelism between the two provinces is an important for the estimation of rifting controlling factors and driving forces.

CRATONIC ROOTS, MANTLE PLUMES, AND THE EAST AFRICAN RIFT SYSTEM

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The 3500 km-long East African rift system transects lithosphere ranging in age from Archaean to Late Mesozoic passive continental margins, allowing one to assess the relative importance of lithospheric strength/lateral variations in lithospheric thickness on rifting processes. Geophysical, geochronological, and geochemical data all suggest that all or parts of the rift system are affected by mantle plume processes. We investigate the influence of pre-plume, pre-rift topographic relief at the lithosphere-asthenosphere boundary beneath East Africa on the distribution of hot, buoyant plume material emplaced at ca. 45 Ma. Our models show deflections of plume material around the thick cratonic root beneath the Tanzania craton, and selective ponding of material beneath the Mesozoic rifts and passive margins, which had thinner lithosphere at the onset of plume activity. One of the most important aspects of this plume model is the enhanced vertical flow velocities along craton boundaries, suggesting they exert a strong influence on rift development and location.

NEW GEOPHYSICAL CONSTRAINTS ON THE WEST ANTARCTIC-RIFT-TRANSANTARCTIC MOUNTAINS TECTONODYNAMICAL SYSTEM

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The West Antarctic Rift system is one of the largest modern rift systems in the world. Previous aeromagnetics supplemented seismic findings in the western Ross Sea and in the Byrd Subglacial Basin by revealing extensional rift fabric, variable volumes of likely late Cenozoic alkaline volcanics and transfer faulting. The volcano-tectonic activity, suggested to be plume-driven, might involve greater lower lithosphere extension than limited late Cenozoic crustal extension. New regional aeromagnetics along the Transantarctic Mountains rift shoulder in Southern Victoria Land, reveal Cenozoic faults oblique to the offshore rift basins and different Paleozoic inherited basement compared to the north, maybe explaining more moderate rift flank uplift here. Recent wide-angle seismics and gravity links this Cenozoic uplift to crustal extension and magmatic underplating, as shown also by high electrical conductivity at depth. In Northern Victoria Land pull-apart basins are defined from magnetics and gravity. These formed in response to a Cenozoic transtensional reactivation of basement terrane boundaries, consistently with the kinematic regime proposed from brittle fault data onshore and seismic evidence offshore. In Marie Byrd Land, along the eastern rift flank, magnetic anomaly patterns are also related to Cretaceous mafic magmatism and faulting during older transtensional rifting, triggered by subduction.

CRUSTAL MELTING OF VOLGA-URAL OIL BEARING PROVINCE BY ACTION OF VOLGA-KAMA'S PLUME

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The Volga-Ural Oil Bearing Province is a classical example of the gas and oil bearing region that was exposed over a long period to the influence of subduction processes. Here the process of collision between Russian craton and Siberian plate has been going over the last 200 – 250 mln. years. The clear relation of power heat anomalies in lithosphere to regions of linear and polygonal spreading of trans-regional rift structures points out on an important part of differentiation of deep mantle matter in the formation of oil-bearing province. The mantle heat from the Volga-Kama plume creates the thermodynamic condition for accelerated transformation organic matter into oil. Lithospheric inhomogeneities of the Volga-Kama plumes such as the pluto-like bodies, as the Moho-discontinues uplifts and heat fluctuations are modelling and are observed. The melting mushroom-like plume moves under the plate in the south-east direction with the rate $10 \pm 2mm/y$ in the local hot spot frame. Its action is traced in the crust a) in the form of arched lineament chain, b) by divergent horizontal heats flow from hot spot epicenter (50°N, 53°E) and c) by dependence of oil density (from heavy to low one) in deposits with the distance from the modern plume location.

Mantle lithosphere R-T instability, FEM modeling of convective upwelling of mantle lithosphere beneath rifts zones.

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We present quantitative FEM modeling results of the dynamic interplay of intra-plate stress driven passive extension and Raleigh-Taylor instability of the mantle lithosphere due to lateral and vertical density gradients. We employ a two-dimensional finite element code with a non-linear temperature dependent visco-elasto-plastic rheology. The model results support a scenario in which passive stretching leads to an unstable lithospheric configuration. In the late syn-rift to early post-rift thermal buoyancy related to asthenospheric doming drives active upwelling in a lithospheric scale convection cell causing a change from passive to active rifting mode. If this transition occurs, the numerical models predict 1) drastic increase of sub-crustal thinning beneath the rift zone, 2) lower crustal flow towards the rift flank, 3) middle crustal flow towards the rift center, 4) significant decompression melting, 5) coeval occurrence of tensional stresses within and compressive stresses around the upwelling region, 6) possible surface uplift. The model results may explain several key observations that are characteristic of a large number of intra-continental rift basins. These features include differential thinning of extending lithosphere, the discrepancy between fault related extension and crustal thinning, late (end of syn-rift - early post-rift) mantle related volcanism, surface "domal" uplift succeeding rifting, rift flanks uplift associated with extension of a weak lithosphere (shallow level of necking case), and late stage acceleration of subsidence caused by compressive intraplate stresses. Very large scale thermal anomalies of the shallow asthenosphere may explain the observation of coeval rifting of basins far apart and the isotopic and geochemical similarity of the rift related shallow mantle alkaline volcanics. E.g. the Miocene age Western and Central Europe rift system. We propose that the increase of the asthenosphere temperature may trigger secondary R-T instable growth of variations in the lithosphere thickness and induce acceleration of already active but not very efficient rifts. In this way passive rifts that were already active may show a transition from passive to active rifting.

AN OVERVIEW OF THE STRUCTURE AND EVOLUTION OF THE RIO GRANDE RIFT, SOUTHWESTERN NORTH AMERICA

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Over the past 15 years, the Rio Grande Rift has become recognised as a major continental rift. Its development began 30 m.y.a. and continues today. This rift sets on the crest of a broad linear uplift which forms the modern Rocky Mountains and is underlain by a region of hot upper mantle as revealed by seismic and gravity studies. The rift zone itself is similar in scale to the Kenya rift. It begins in central Colorado and extends southward across New Mexico into northern Mexico. As it extends southward, the physiographic expression of the rift widens, the elevation of the flanks and rift valley decreases, the crust thins, the amount of extension increases, and the rift merges with the Basin and Range province. The crustal expression of the rift is clear with the minimum thickness being ~28 km. However, the mantle lithosphere is also effected by the related Jemez volcanic lineament which teleseismic studies show also produces lithospheric thinning. The rift basins are very deep containing up 5 km of young fill in addition to a significant thickness of pre-rift volcanics and post-Laramide sediments. One well drilled to almost 7 km without leaving Tertiary strata. Volcanism in the past 15 Ma. as been primarily basaltic and small in volume. However, large, subduction-related volcanic fields flank the rift, and although the peak activity in them preceded the onset of rifting, considerable volcanism occurred during the early phase of rifting. Thus, the tectonic history of the region just prior to rifting was very complex.

THE KRISP INVESTIGATIONS OF LITHOSPHERIC STRUCTURE AND DYNAMICS OF THE KENYA RIFT

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The Kenya Rift International Seismic Project (KRISP) included three major seismic experiments supplemented by gravity, conductivity and petrological studies. These indicate anomalously hot mantle material rising beneath the rift about 20-30 Ma ago leading to widespread volcanism and modification of the crust by mafic igneous underplating and intrusion. This was accompanied by 5-10 km of crustal extension beneath the Kenya dome and 35-40 km beneath the Turkana depression in the north part of the rift. The velocity structure in the uppermost mantle suggests that the depth to the onset of melting under Turkana is greater than under the Kenya dome. The crustal structure across the rift in the south suggests that it is propagating along the suture between the Archaean and Proterozoic terrains.

STRUCTURE OF THE CRUST AND UPPER MANTLE BENEATH THE BAIKAL RIFT FROM TELESEISMIC AND LOCAL TOMOGRAPHY

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We investigate the velocity structure beneath the Baikal rift zone (BRZ) and surrounding areas (Altai, Sayan and northern Mongolia) by using both conventional (far-distance earthquakes) and inverse (regional sources recorded by the worldwide network) teleseismic schemes. The inversion shows the existence of parallel N-S-striking alternated velocity anomalies beneath Siberia: Altai [+], L.Ubsu-Nur [-], Sayan [+], L.Hubsugul [-], Baikal folded system [+]. At the BRZ latitude, we observe a strong velocity gradient parallel to the border of the Siberian shield. We interpret it as a narrow plume injected within the lithosphere along the suture bording the shield. It might weaken the lithosphere in the suture zone which locally undergoes rifting in response to far-field tectonics. We then use local earthquake traveltimes to study the velocity structure beneath the BRZ down to 70 km depth. Our iterative procedure includes effects from the reference model, source relocation, and 3D inversion of velocity anomalies. The model obtained shows a strong P-velocity reduction below the Baikal folded area in the shallower part of the lithosphere (0-30 km); deeper levels (30-70 km) show features striking oblique to the BRZ. We find a good correlation between volcanism and deeply-rooted [-] anomalies around Hubsugul lake. Underplating can be invoked in the northern BRZ. These results lead us to conclude that a mantle diapir cannot be the dominant reason for rifting in the Baikal area, as assumed in previous studies.

ACTIVE DEFORMATION MECHANISMS IN THE BAIKAL RIFT ZONE USING TWO-DIMENSIONAL NUMERICAL MODELS

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We use a two-dimensional finite element code to model deformation in the Baikal rift along a lithospheric scale cross section. Kinematic boundary conditions were constrained by the results of 4 GPS campaigns, giving an average extension rate of 6 mm/yr in a direction perpendicular to the rift. We assume an initial topography, an elastoplastic (Drucker-Prager's law) upper crust and upper mantle, and a viscoelastic lower crust. The geometry of the faults and lithosphere interfaces is deduced from geological and geophysical observations. A single SE-dipping planar fault reproduces rather well the central rift assymetry. The modeled rift shoulders are strongly dependent on the friction and geometry of this fault and on the mechanical properties of the crust. The uplift of rift flanks can be mostly explained by a flexural response to mechanical unloading. The models also predict significant deformation up to 200 km away from the rift axis, to the SE, where the basin-and-range type of topography could therefore be partly related to the current opening of the Baikal rift associated with a high crust-mantle decoupling on Khamar Dhaban range side.

WIDE-ANGLE REFLECTION STUDY OF LOWER CRUSTAL MAGMATIC PROCESSES IN THE KENYA RIFT

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Recent geophysical and geological studies in the Kenya Rift have highlighted mantle processes as being responsible for lithospheric extension. Interpretation of the Kenya Rift International Seismic Project (KRISP) 1994 seismic and gravity profiles across the southern part of the Rift shows that the extension has been focussed along the orogenic suture between the Archaean Nyanza craton and the Proterozoic Mozambique orogenic belt. The surface expression of the suture has been obscured by a thin sheet of deformed Proterozic basement that has been thrust 150km over the craton margin to the west. A small amount of crustal thinning beneath the rift axis indicates a pure shear mechanism at depth. Wide-angle reflection bounce points within the rift demonstrate the lowest crustal layer as being highly reverberative, while outside the rift no such reverberations are seen. Petrological considerations and synthetic seismogram modelling suggest that cumulate layering in magma chambers and/or sills may be the most reasonable explanation for the production of the reflection signature. The results are significant to our understanding of how magma ascends from the upper mantle through extending continental crust.

THE STRUCTURE AND EVOLUTION OF THE KENYA RIFT

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The seismic experiments carried out between 1985 and 1994 as part of the Kenya Rift International Seismic Project (KRISP) show major variations in lithospheric structure both along and across the rift. Along the rift axis crustal thickness varies from 35 km in the south beneath and to the south of the Kenya dome to 20 km in the north beneath the Turkana region. Seismic profiles completed in 1990 and 1994 across the rift north and south of the Kenya dome both show that the low uppermost mantle P_n velocity of 7.5-7.8 km/s and crustal thinning up to 10 km is confined to below the surface expression of the rift. An abrupt change in Moho depths and P_n velocities occurs as the rift boundaries are crossed. Teleseismic tomography of the P-velocity structure beneath the central part of the rift reveals a steep-sided low-velocity body extending down to 100-150 km depth beneath the surface expression of the rift. The maximum anomaly is located where the Proterozoic Aswa suture zone intersects the Cenozoic rift at the location of the Kenya dome. The results indicate the presence of a few percent of partial melt in the mantle beneath the rift and, at least beneath the Kenya dome in the southern part of the rift, that active uprising of anomalously hot mantle material with thinning of the lithosphere from below is the dominant rifting mechanism.

MODELLING LATERAL EXTENSION AND RIFTING IN A STRATIFIED LITHOSPHERE WITH APPLICATIONS TO THE AFRO-ARABIAN RIFT SYSTEM.

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We present models which simulate the interplay between lithospheric spreading rate versus mantle upwelling rate in rift dynamics. In models with mantle upwelling rates much faster than crustal spreading rates, the domal uplift and the vertical and lateral development of crustal failure was controlled by the rising mantle diapir. The diapir localised the extension by thinning the ductile crust. In this mode domal uplift preceeded the localization of a necking instability and subsequent graben formation.When lithospheric spreading was faster than rate of rise of a mantle diapir, listric normal faults and spaced grabens developed at a wavelength much wider than the lateral width of the underlying mantle diapir. In this case the mantle diapir played a passive role and was mainly involved in the modificaiton of subcrustal detachments which developed previously in respone to the differential lithospheric extension.The Dynamic models are applied on different parts of the Afro-Arabian rift system whose distinctive structural styles may reflect lithospheric spreading operating at different rates. The Ethiopian rift is taken as a test case of the "active" mechanism of rifting above a mantle plume rising faster than lithospheric extension. By contrast, the Red sea may have opened after major lithospheric extension along sub-horizontal detachments in response to divergence of the Arabian plate contemporaneous with subduction in the Zagros.

RIFTING AND FLEXURE OF THE CONTINENTAL LITHOSPHERE: COMPARISON BETWEEN THE EAST-AFRICAN AND BAIKAL RIFTS

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In this study, we compare flexural gravity models of the East-African and Baikal rift zones in order to estimate the variations of the lithospheric strength, and assess the flexural behaviour of the lithosphere and the origin of the observed topography in two active rift zones. Lithospheric extension generates thermal disturbances and isostatic reactions expressed in vertical movements (basin subsidence, rift flank uplift). The mechanical response of the lithosphere is mainly controlled by the rheology, the pre-rift lithospheric structure, and the strain rate, which determine the rift morphology and the style of the extensional deformation. As shown by gravity and topography modeling, the formation of long-lived high rift flanks imply that the lithosphere must retain strength during extension. The integrated lithospheric strength is usually described by the effective elastic thickness parameter (EET). However, modeling the flexural rigidity of the continental lithosphere requires us to take into account more realistic brittle-elasto-ductile (quartz-dominated crust/olivine-dominated mantle) rheology. These mechanical models allow to account for a realistic stress distribution in the lithosphere, and for the distribution of inelastic brittle and ductile behaviors. This study shows that in both rift zones, the lithosphere still exhibits an important strength, especially in the old cratonic areas bounding the East-African and Baikal rifts.

THE BAIKAL RIFT AS STRUCTURAL EXPRESSION OF PRE-EXISTING LITHOSPHERIC INHOMOGENEITIES IN CENTRAL ASIA

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Cenozoic rifting in the Baikal region (East Siberia) is remarkable by strong influence of pre-existing lithospheric inhomogeneities on its style and character as it is one of repeated tectonic episodes in the region. Among other specific features of Baikal rifting, inferred from analysis of geological and geophysical data, are its coincidence in time with collision between India and Eurasia, small volume of rifting-related voclanism, geophysical deep structure images of little contrast against those of adjacent cratonic areas, poorly pronounced position of the asthenosphere beneath the rift, shown ambiguously by different geophysical methods. Finally, the rift is isolated and has no evident relation to the world rift system. These facts taken in consideration, a new rifting mechanism is proposed, that reconciles the "passive" and active" models. The mechanism is based on the hypothesis that energy feeding active areas, rifts included, is not due to hotspots beneath them, but rather to heat accumulated under adjacent cratons and transported by divergent mantle flow towards craton margins.

CRUSTAL STRUCTURE OF BAIKAL RIFT - INHOMOGENEITIES AND EVOLUTION THROUGH GEOLOGICAL TIME

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Xenoliths are «instant picture» of the lithospere's state. Crustal xenoliths of Cenozoic basalts in the Baical rift zone and its continuation to N. Mongolia contain some traces of partial melting connected with intergranular shearing. As a result, the substance of deep-crust's layers is transformed into two-phase mechanically mobile medium. Some peculiarities of Palaeozoic structure of the crust were studied by mapping granite-gneiss domes of Western Baikal Area. «Moire patterns» were recognized from large-scale airial photographs (1:3000 and larger). These «moire structures» are composed of vertically elongated «cigars», blisters, tubes which are supposed to be fluid-conducting channels. A 1D nonstationary mathematical model of the soliton-like fluid motion, based on the mechanics of porous saturated media with a viscous (compacted) skeleton, is developed.

THE OKINAWA TROUGH: CONTINENTAL RIFTING IN A BACK ARC SETTING

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The Okinawa Trough is located at the Southeast continental margin of the East China Sea, behind the Ryukyu Trench and the Ryukyu active volcanic arc. It provides an excellent example of an active rift at perhaps the most advanced stage (a stage between East African and the Red Sea) of the modern continental rifting process in the world.

The activities of the present-day Okinawa Trough are exhibited by a variety of geological and geophysical phenomena among which are extremely high and variable heat flow (a mean value of 548 mW/m^{2}), strong and frequent earthquakes, high gravitational anomaly, active volcanoes and faults, high subsidence rate, active hydrothermal mounds, etc. Although the most widely distributed volcanic rocks

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ted in the rifting process in full swing with large scale volcanic and hydrothermal activities, although so far the stage of sea floor spreading is yet to come. Deep seismic and deep drilling at selected sites in the Okinawa Trough would shed new light on the thorough understanding of continental rifting process, which in turn provide insights into the mechanism and evolution of widely developed Tertiary rifting basins in East China.

SE15 Crustal structure revealed by scientific drilling

Convener: Lauterjung, J.

STRUCTURE OF THE UPPER CRUST IN SG4 BOREHOLE AREA FROM VERTICAL INCIDENDE AND VSP DATA

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The upper crust in the Middle Urals shows a high reflectivity which has been partly addressed to low velocity/density zones: fault zones. The SG4 borehole area (Tagil Volcanic Arc-Middle Urals) has been densely sampled with surface reflection seismic data (ESRU95-Juhlin et al.1997, in press) and VSP data (VSP94-Juhlin et al. 1997, VSP97-Ayarza et al. 1997) in order to find accurate correlations between reflections and faults identified on maps and therefore infer the 3D structure of the area. On the VSP97 data, reflective events are found intersecting the borehole at (A)1500 m, (B)2900 m, (C)4800 m, and (D) 5200 m.These correlate with NS/E dipping reflectors on the ESRU95 data. However, the most reflective and continuous event observed in the VSP97 data (E) does not appear to have a clear signature in the ESRU95 data, hindering its correlation with a precise fault zone. Rotation of the VSP97 3 component data provides a method of identifying the arrival direction of the direct and reflected energy and therefore, gives an approximate strike and dip of the reflectors. Modelling of the travel times further constrains their dip. A NS/E dipping fault appears again to be the source of the energetic event (E). It is not clearly observed in the ESRU95 profiles due to the lower resolution of the dataset. Polarity analysis of reflected events add further constrains on their origin.

$J(NO_2)$ at Ny-Ålesund: Measurements and Model Calculations

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The photolytic rate constant of NO_2, $J(NO_2)$, has been determined using two independent methods at the *Ny-Ålesund International Arctic Research and Monitoring Facility*. NILU has operated since 1994 a $J(NO_2)$ radiometer, and additionally during 1995/96 a UV filter instrument. The results of the latter are used as input in a radiative transfer model using the discrete ordinate method to calculate $J(NO_2)$ rates.

In this paper we present the measured quality controlled $J(NO_2)$ timeseries from the radiometer, and compare noon-time values with model results. Implications for background Arctic photochemistry and the tropospheric ozone budget are discussed.

NEW DATA ABOUT PECULIARITIES OF PHYSICAL PROPERTIES IN THE KOLA SUPERDEEP HOLE

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A study for petrophysical, geothermal, hydrogeological zonation for Kola hole is presented. Hydrogeological zonation for Kola can be divided into 4 parts. Permeable zone, associated with exogenous issuring (0-800m). Zone of joint (free and chemically bounded) waters (800-4500m). Zone of regional tectonic foliation and hydraulic desegregation of rocks, with free high saline waters (4500-9200m). Zone of joint waters, mainly chemically bounded with vein-type reservoir for free water (>9200m). Zones III and IV are associated with riftogenic evolution of Pechenga Greenstone Belt. Fractures were formed during dehydration processes in a closed system. 4.5 km depth-boundary is assosiated with sharp change of petrophysical properties of the rocks: seismic velocity, porosity and density. It was established that mechanical state of geomaterials is responsible for this phenomena. For the upper part of Kola section we can explain heat flow density increase with depth as a result of subvertical water flow and influence of paleoclimat. Deeper than 4.5 km rocks are fractured and water saturated. For observed geothermal parameters we need to check factors like refraction of temperature field, free water convection in the caving hole and in fractures, degree of representation of rock samples for in situ conditions to understand the result of measurements.

THE 3-D ANISOTROPIC-STRUCTURAL MODEL FOR THE SECTION OF KOLA SUPER DEEP (KSDB-3)

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The Earth's crust investigation, recently promoted by direct methods of extracting rock samples from super-deep boreholes, allows one to make the ideas about the geospace structure more precise, at least in the range from 0 to 15 km. The quantitative description of elastic anisotropy is made by an acoustopolarization method along the whole section of KSDB-3 to the depth of 12.26 km. Some rocks of Proterozoic complex (4.43-6.84 km) and practically all Archean rocks display rather strong anisotropy. Rocks of orthorhombic symmetry with oblique arrangement of symmetry planes to the borehole axis prevail. From the surface to 12.26 km of crystalline rocks ten structural-anisotropic floors have been distinguished by anisotropy parameters. The floors differ in dip angles, a trend azimuth of anisotropy plane, the value of anisotropy index. The boundaries of structural-anisotropic floors and the suite and stratum contacts within Proterozoic and Archean complexes, as a rule do not coincide. The current status of theory and practice of geophysical observations, carried out on the earth's surface, does not yet allow one to specify a symmetry type and other data in not exposed rocks with certainty. Thus, scientific programs, using deep and super-deep wells, are necessary to develop algorithms for processing geophysical work results in the regions of anisotropic rocks occurrence.

TEMPERATURE DISTRIBUTION AND ANOMALIES IN THE CRYSTAL BASEMENT

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Our experiments in ultradeep and deep boreholes on the East European platform have revealed temperature anomalies in the crystal basement that we interpreted as representing unconsolidated zones. Despite much local complexity, basement thermogram (large-scale variation) appears to be fairly uniform. The most important feature in the temperature distribution with depth is the large-scale homogeneity and heterogeneities on a smaller spatial scale. Various temperature anomaly types have been observed in the crystal basement, and they are classified in 9 main groups. They have various form and sizes. There are strata of large thickness at great depths where T anomalies concentrate. The studies indicate that fluid injection anomalies, sheet flow zones and gas anomalies with sharp and extensive transitions from inpermeable to permeable rocks could be revealed on the basis of temperature measurements. For many zones of the basement the flow dynamics processes leading to temperature anomalies are becoming understood, for some zones our knowledge is not adequate. Whatever the sources that contribute to the anomalies most of them are zones of convective heat-mass transfer. Especially important is the accumulating evidence that these unconsolidated zones occur at great depths in the crystal basement and that their thickness and magnitude increase with increasing depth. The temperature regime will have a greater tendency toward T inhomogeneity and temperature anomalies will be larger.

CRUSTAL STRUCTURE REVEALED BY SCIENTIFIC DRILLING OF THE KOLA SUPERDEEP BOREHOLE

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Scientific drilling of the Kola Superdeep well (12262 m) car- ried out in the northern-eastern part of the Baltic Shield has allowed to get the immediate information on physical-mechanical properties of the deep horizons of the ancient earth crust "in situ" and to perform a monitoring on the variations in their state with space and time. The analyses of the petrophysical material combined with pet- rochemical and lithologicals stratigraphic data have permitted to de- termine experimentally the origin of the waveguides in the earth crust governed by the fractal properties of the media. This universal pro- perty is defined not only by the structural-substantial peculiarities of the rock, but also by their complex-stressed state. The anomalous state of the media in the lower horizons of the earth crust and mantle is a result of deep spreading of the faults and attendant fracturing. In spite of the depth increase the following characteristics are noted in these horizons: lessened velocities of seismic waves propagation, high permeability of the geological media, drastic drop of strength, relatively low temperature (200- 600o) and "low" pressure (200-1000 MPa).

KTB DEEP CRUSTAL LAB - EXPLORING THE DEEP ON THE LONG-TERM

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The worlds deepest earth observatory is operated by the GeoForschungs-Zentrum Potsdam, GFZ, since January 1996 in the 9101 m deep main borehole and the nearby 4000 m deep pilot hole of the German Continental Drilling Project, KTB. The GFZ as a main geoscientific research institute in Germany, provides the logging equipment on-site. Within five years major scientific targets of continental drilling, like temperature gradient, magnetic and gravity field, hydraulic and rheological rock properties and tidal effects, will be investigated. Mainly by long time observations of time dependent processes in the crust, unaffected by the constraints of an active drilling. A deep seismological observatory records worldwide seismicity with stations at 3800 m and 7200 m far below any anthropogenic surface noise. Deep gravity and seismic measurements are performed within and below the major steeply dipping thrust fault zone at around 7 km. New sondes have been developed for long-term measurements under the extraordinary KTB conditions (250 °C and 100 MPa). Interested institutes and companies are invited to contribute to the program.

LOGGING FOR STRUCTURES AND CRUSTAL COMPOSITION IN THE SCIENTIFIC BOREHOLE URALSKAYA SG-4.

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The Ural Superdeep Well SG-4 is located in the Middle Urals in an area with a long history of geophysical studies. Major goals of the project are to investigate the Uralian upper crustal composition and the nature of seismic and other geophysical boundaries. The project consists of a pilot hole down to 4000 m and the main hole which reached an actual depth of 5354 m. A broad set of laboratory investigations have been performed on the continuous core (recovery rate 65 %). Wireline data exist down to 4000 m and extensive borehole seismic experiments were conducted recently. Logging data play a key role in providing the link between large scale seismic investigations and small-scale core data. The present wireline and core data set indicate that many of the upper crustal seismic reflections correlate with major fracture zones. However, for other reflections it is not clear whether they originate from structural or lithological discontinuities. Correlations between core analyses and log data show some of the logs (egs. susceptibility and gamma-ray log) to be strongly related to rock composition. Others are sensitive to fault and fracture zones. Thus, integrated log analysis allows the discrimination of the compositional and structural origins for the in-situ physical property variations. Future work is targeted to performing downhole measurements also in the deepest part of the borehole (below 4000), log Vp and Vs velocities in the upper 4000 m and to link the seismic data to detailed log and core data.

STRUCTURE AND TECTONIC STRESSES IN OCEANIC BASEMENT HOLES DRILLED BY DSDP AND ODP.

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Scientific drilling provides a unique means to investigate present tectonic stresses in the upper crust from rupture of borehole surfaces and drilling-induced shear of pre-existing fault planes. While borehole ellipticity analyses are used to orient the stress tensor, the re-activation of fault planes can lead to the evaluation of stress magnitude. For example, downhole measurements and images recorded in metamorphic basement during ODP Leg 161 (Alboran Sea, Hole 976B) have been analyzed with this objective. Hole ellipticity is rare and often associated with changes in hole trajectory. A few narrow intervals with sharp changes in hole geometry are found to correspond to active faults from BHTV images. While 20 such faults are detected over a 80-m-long interval, the mapping of fault planes and drilling-induced slip vectors leads to the identification of an extensional tectonic regime, with the minimum stress axis pointing N080°. If S_1 is considered as lithostatic, the magnitude of the three principal stresses may be determined as a function of the friction coefficient (μ). This new result is compatible with an extensional collapse model of the Alboran basin. Similar drilling-induced ruptures are also identified in numerous DSDP and ODP holes penetrating structures created along mid-ocean ridges.

GEOPHYSICAL INVESTIGATIONS ON THE BASE OF THE KOLA SUPERDEEP BOREHOLE

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Seismic investigations were carried out by method of vertical seismic profiling during long period of time with the purpose of studying: ve- locity and damping of elastic waves in the vertical section of boreho- le SD-3, complex wave field, nature of seismic boundaries in the upper part of the earth crust (in particular subhorizon boundaries registe- red by DSS method (Deep Seismic Sounding) at the depth of 5-7 km and 9-13 km). The diagram of layer velocities of longitudinal waves for SD-3 section was constructed up to the depth of 12 km. Discovered by DSS method subhorizon seismic boundary with the velocity of 6.5 km/sec (surface of "basalt layer") was not confirmed on vertical velocity section. On the base of geological-geophysical researches it was de- termined that region of the Kola well SD-3 is connected with extended active tectonic zone of high permeability. Tectonic activity and fluid mobility there decrease with depth. Anomalous zone is characterized by lower seismic velocity (waveguide). SD-3 crossection investigations gave possibility to determine the high permeability zones at different depths.

SEISMIC TOMOGRAPHY IMAGE OF THE AREA NEAR THE URALS SUPERDEEP BOREHOLE SG4

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In March 1997, a new VSP experiment was acquired in the vicinity of the SG4 borehole (Tagil Volcanic Arc, Middle Urals). 15 shots of high resolution data, were recorded on 3 component geophones, located at depths between 1120m and 3920m at 20m intervals.

The data set consists of first breaks of both P and S waves from the VSP dataset. P and S traveltimes were used for inversion of the 15 shots. A genetic algorithm was used to solve the non-linear forward and inverse problem. An initial model with a positive gradient with depth was used. A ray initializer method (Thurber et al.,1980) was used as a rapid ray tracing solution. After that, curved raypaths were applied using the ray bending revisited method (Moser et al., 1992). The bending method picks up the initial path by the ray initializer method and uses Beta-spline functions and the conjugate gradient method, making a succesive minimization of traveltimes. The inverse problem was solved using Singular Value Decomposition with damping and smoothness factors.

The Poisson's ratio was calculated and defines "weak" regions, indicating where possible fracture or fault zones may exists, as well as more mafic rock.

ORGANIC CARBON DISTRIBUTION IN SEDIMENTARY COVER OF THE PACIFIC AND INDIAN OCEANS

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Analysis of data on the content of total organic carbon (TOC) in sedimentary cover of the Pacific and Indian Oceans (the results of drilling up to 1996 yr. DSDP and ODP, holes No 1-869) was made. As a result average TOC concentrations for epochs of Cretaceous and Cenozoic were estimated as well as character of their temporal changes. The six maps of TOC distribution in deposits of upper Cretaceous, Paleocene, Eocene, Oligocene, Miocene and Pliocene were constructed on the base of palinspastic reconstructions wich were compared with the maps of TOC distribution in recent bottom sediments. Evolution of TOC distribution is evinced as increase of average TOC concentrations in deposits from upper Cretaceous to Holocene. The regularities of TOC distribution in sedimentary cover were controlled by complex set of factors, first of all tectonic and climatic ones which governed circulation of surface and undersurface waters, enhancing and spreading of coastal upwellings, fluxes of nutrients to euphotic zone, marine productivity and flux of organic matter (OM) to the seafloor, input of terrigeneous OM from land mainly as dissolved and particulate OM of river run-off. As in present-days various rate of burial of OM resulted diverse preservation of OM under anoxic and oxidative conditions.

SE16 3-D crustal imaging of France

Convener: Ledru, P.
Co-Conveners: Fuchs, K.; Galdeano, A.

A NEW COMPILATION OF THE AEROMAGNETIC DATA OF MASSIF CENTRAL, CORRELATION TO GEOLOGICAL AND GEOCHEMISTRY DATA (GÚOFRANCE 3D PROJECT).

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This geophysical study was done within the frame of the metallogenic project of GeoFrance3D program. A new compilation of two aeromagnetic surveys realized in the Massif Central in 1972 and 1975 has been compiled at an altitude of 1200 m. A 500 x 500 m grid spacing has been obtained. Several aeromagnetic maps (reduction to the pole, upward and downward continuation, vertical gradient) have been processed. In this study, focussed on granitic recognition, gravimetric, geological and geochemistry data have been integrated. Granites have a particular implication in hydrothermal fluid transfert and deposition of mineralization then, their geometry is important for the metallogenic process understanding. Geophysical study, magnetic coupled with gravimetry, allows to show up buried granites and to evaluate their geometry.

3D MODELING OF THE BLOND AND VEYNAZES GRANITIC MASSIFS

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Within the GeoFrance3D program, results of a gravimetric inversion are imaged using gOcad 3D modeler with application to the Blond and La Chataigneraie (Veynazes and Marcoles) granitic massifs (French Massif Central). The Blond Leucogranite massif appears as a V-shaped granite 3 km thick. In its southern section, a deep zone (6 km), oriented N60E, is observed close to the Oradour dextral fault. This fault controls the granite emplacement. The northern part has a laccolithic shape (< 2 km) with deeper zones trending EW with more evolved rocks. The morphology of both Marcoles and Veynazes massifs is very flat (< 2 km). Two minima are observed, the first one (2.5 km) just under Labesserette, the second one under Marcoles (1.25 km). The two massifs are connected, but density modelling clearly shows an eastward buried infiltration of the Veynazes toward the Marcoles massif. Buried extension (on 3.5 km) of the Veynazes granite is also observed to the north, connected to W mineralization.

SHALLOW CRUSTAL IMAGING OF ARMORICAN BELT FROM ARMOR SEISMIC PROFILE

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The ARMOR AR2 deep seismic profile data, recorded in 1995 in the northern part of the Armorican belt, have been inverted in order to obtain the superficial velocity field until 600 meters depth. First breaks from unit shots are first picked and taken as the observed traveltimes data set. An initial velocity model is then built from a modelling stage and shots interpretation. An iterative algorithm, based on damped least squared method, is used to invert the data, until the velocity model converge to an acceptable velocity model. This one shows up a 60 meters thick layer overcoming a thicker layer. Strong lateral variations of velocity are observed in the central part of the profile; This corresponds simultaneously to a low velocity zone and to the first layer thickening.
The features of weathering profiles physical properties in the Armorican context are determined from electric soundings and 50 meters depth drillings. They allow us to explain the low velocity zone as a shallow weathered zone corresponding likely to a continental paleosurface. The thickening observed in the central part of the profile occurs when passing throught the North Armorican Shear Zone. At this location, low velocities are also obtained in depth beneath the weathered zone, underlining the strong influence of deformation and fracturation on weathered development.

3D MODELLING : FROM CROSS-SECTION EDITOR TO GEOPHYSICAL COMPUTING

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Geological bodies are naturally complex because they result from a succession of events that have led to their present morphologies. In order to understand them, maps, sections, drilling, seismic profiles are used to reconstruct their geometry. Three dimensional modelling is an essential tool to merge all these 1D and 2D data in a unique 3D space. A cross-section editor is used to ensure 3 dimensional geometric coherence of data coming from different sources but describing the same study area. Then, an automatic method based on Voronoi diagrams is proposed for the 3D volume reconstruction of geological objects.The resulting geometrical model is a consistent partition of space according to data specifications. The model is illustrated through a 3 dimensional image which can be easily shared by a wide audience. Moreover, constructing this geological model serves to test the hypotheses on which it is based. The structure of the geometrical model allows to perform potential field calculations. Densities (respectively magnetic susceptibilities) are associated with modelled geological bodies to compute the gravity (respectively magnetism) contribution. By comparison between observed and calculated field, the model is refined to fit the observations. Methodology is applied on Argentat fault area (South-Western French Massif Central) and the Cadomian terranes (Northern French Britanny) examples from the GeoFrance 3D program.

CONTRIBUTION OF SAMPLE MEASUREMENTS TO MAGNETIC MODELLING OF THE FRENCH CADOMIAN BELT

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The French Cadomian belt (Northern Armorican Massif) is a privileged area for studying the Panafrican orogeny processes. Direct magnetic modelling was computed along profiles extracted from a detailed aeromagnetic map and constrained by the geometry of thé magnetic bodies and their magnetizations. The last ones have been calculated from a data base of about 350 rock samples. Sample measurements show that the NRM is negligible. So only computed mean induced magnetizations were attributed to each magnetic body. The strongest magnetizations and the strongest anomalies are associated with the same formations. The Binic basin was modelled with a large wavelength folded shape and reaches about 2km depth. The St Quay intrusion intrudes the Binic basin at its centre with vertical contacts. The modelling imposes that this intrusion appears composed of two magnetic bodies in its eastern part and of one single magnetic body in its western part. The southern limit of the basic part of the Lanvollon formation is modelled fromvertical to strongly dipping to the north. The Lanvollon Formation exhibits an heterogeneous magnetic behaviour consistent with lithology made of intercalated acid and basic metavolcanic bodies. In addition, from the eastern to the western profiles, the magnetic modelling points out a difference of thickness in the acid part of the Lanvollon formation. We propose to relate it to initial variation of the thickness of the acid volcanic bodies.

LITHOLOGIC INVERSION FROM PLURAL GEOPHYSICAL DATA

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A new probabilistic based methodology allows to formalize the problem of integrating information from: (1) different types of geophysical surveys, (2) petrophysics and geostatistics and (3) prior geological knowledge of the area. The methodology requires a joint representation of several media properties in the model and the use of probability density functions (pdfs) to describe the information. From the combination of the plural information the joint posterior pdf is defined. A Markov-chain Monte Carlo method is developed to sample joint models from the joint posterior pdf. Each one of these models represents an equally probable image of the volume under study and the statistics calculated over the sample allow to estimate the true properties and its uncertainties. The method is illustrated by a 2D synthetic test and a 2D example using data from the Cote d'Armor region.

ANALYSIS OF SURFACE WAVES IN THE FRENCH ALPS BY A DENSE BROAD-BAND STATION ARRAY

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During 6 months in 1996, 6 broad-band stations were installed in the french Alps, near Briançon (Hautes-Alpes) for the GéoFrance3D program. The stations were disposed as a circle and the aperture of the array was approximately 25 km. The purpose of such a small array is to study the local variations of surface waves parameters (dispersion, amplitude, polarisation) and finally to determine the crustal structure in the Alps. We measure first the back-azimuth for teleseimic events recorded by this array. The method used is based on the delay calculation between 2 stations for a moving window in the time domain. These delays are inverted to determine the slowness in the space directions. Results from the back-azimuth analysis show strong differences between the direct ray and the great circle path. They can reach up to 15° degrees for frequencies between 0.025 and 0.050 Hz, due to the lateral heterogeneities in the crust. This analysis can determine the direction of propagation inside the array, which secondly allows to choose the best pairs of stations to measure the phase velocity. Since in most of the cases the distance between the stations are too small as compared to the wavelength, data coming from other broad-band stations in the Alps are included in our set. Finally, we propose to calculate the dispersion curves of phase velocity between 15 and 60 period seconds.

VALIDATION OF MULTIDISCIPLINARY DATA USING THERMO-MECHANICAL NUMERICAL MODELLING: APPLICATION TO THE WESTERN ALPS

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French Program GeoFrance 3D assembles available multi-disciplinary data on the 3D structure of the lithosphere beneath France and bordering regions, which invokes the difficult problem of validation, compatibility and adjustment of data of different nature, quality and origin. We propose an approach which exploits the natural interdependence between the different physical parameters of the geological structures (density, rheology, temperature, stress, etc.). This is done via incorporation of the multidisciplinary data, as input parameters, in the "uniting" thermo-mechanical model which allows to verify if the mechanical stability, velocity, density and temperature structure of the particular geotectonic region can be reproduced with these input data. The model is based on the FLAC-based algorithm which solves equilibrium problems for media composed of multiple brittle-elasto-ductile structures (including large faults) corresponding to the input density, lithology, temperature and velocity structure. Due to its ability to reproduce strain localizatons without initial pre-refinements of the mesh, our model can additionally predict fault distributions that can be matched with the observations. In case of large errors in the definition of the geometry of the input density bodies, lithologies etc, unrealistic geometries of the internal interfaces as well as unrealistic velocity and stress distributions or synthetic seismic patterns are predicted by our model, thus indicating problematic places in the input data. Tests of our approach on the Alpine orogenic system (ECORS and NFP20 profiles) suggest that some significant corrections must be applied to the seismically predicted geometries of the Ivrea body and of the depleted subducted crust. One of the other interesting results is that the subduction of the lithosphere beneath the Western Alps is seemingly conditioned by the density and rheology of the crust and obviously does not require extra slab-pull forces.

A DENSE TEMPORARY SEISMIC NETWORK IN THE W. ALPS

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In the framework of GoFrance 3D-Alpes, a dense network of seismic stations was deployed in the western Alps (44-45°N,6-8°E). The network contained more than 100 stations: 73 temporary stations installed during the 6-month experiment period (08/1996 through 01/1997), completed by over 30 permanent stations. The main objectives of this experiment were: i) high-precision localization of local earthquakes, with special emphasis on depth determination, ii) computation of focal mechanisms in order to test several geodynamic models proposed for the western Alpine arc, iii) local-event tomographic inversion. The network successfully recorded over 1000 local earthquakes ($-0.5 \leq M_L \leq 4.2$).
The preliminary seismicity maps obtained, based on more than 750 local events, show various striking features. Two major elongated active zones correspond to the Briançonnais Zone (depths 0-10 km) and to the Ivrea Body zone (depths 10-20 km). Other more diffuse active zones are found in the External Domain (depths 0-10 km). The crystalline Pelvoux and Argentera massifs are almost aseismic. Not surprisingly, this activity mimics the activity mapped previously by means of permanent networks. Nevertheless, the density of the temporary network will allow a detailed study of the various faults involved. The timing accuracy achieved through the use of GPS time receivers allows us to perform a cross-correlation analysis of clusters (i.e. doublet analysis). The high number of events, as well as their favourable geographic repartition, provides us with a unique data set for the tomographic study underway.

THE AEROMAGNETIC MAP OF COTENTIN (NW FRANCE)

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A very detailed aeromagnetic survey has been carried out in 1996 covering about 17000 km² of the Cotentin region (North Western France). This survey has been realised at a constant clearance of 400 m. The line spacing was 500 m and the cross line spacing 2500 m. These data have been transformed in a 250 m elementary squared grid. This map shows some magnetic anomalies which are well correlated with geological features. In order to interpret the magnetic anomalies in terms of geological structures, some processing have been done. We computed a reduction to the pole to replace the magnetic anomalies at the top of the sources. We are surprised to notice that the mean amplitude anomalies of this region is very low compared to the amplitude of magnetic anomlies of the aeromagnetic general survey of France (1965), except in some points as Flamanville where we observe an important anomaly with an amplitude of about 800 nT. This anomaly is associated to the Flamanville granite. A part of the well known Coutances anomaly is displayed. We also observe some magnetic anomalies which correspond probably to the continuity of the anomalies observed in Saint Malo region. To the south, the aeromagnetic map shows better structuring anomalies which are probably associated to the dykes system. This map allowed us to underscore some anomalies associated to subsurface structures.

THE MILLION GEOFRANCE 3D PROJECT: A SCIENTIFIC PLATFORM FOR STUDYING WESTERN EUROPEAN LITHOSPHERE

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The GeoFrance3D Million project is a research platform dedicated to study the crustal and lithospheric structures of Western Europe, including France and neighbouring countries. This approach implies the development of the following aspects: (1) to focus on geological problems at the scale of the lithosphere to have access to the geodynamical implications; (2) to merge and reprocess data sets to valorize and extend the old and future acquisitions; (3) to store data in a database and allow their diffusion in the international scientific community; (4) to use geological and geophysical modelling to validate or not the geological concepts. This tasks run in the same objectives defined in the GeoFrance3D program which are to produce 3D views of the crustal structures, and check their reliability by using geophysical simulations. The presented examples illustrate such a methodology applied to the Armorican Moho and Paris Basin modelling, and to the validation of Alpine crustal sections by mechanical constraints. At this time the Million project shows that it was possible to reach new research axes when working at the scale of lithosphere by combining geophysical and geological information. It was specifically shown that data sets merit to be completed in some place either by merging the data sets of the European community, or by planning new acquisitions.

WHAT DO WE KNOW ABOUT THE LITHOSPHERE BENEATH FRANCE FROM SEISMIC TOMOGRAPHY AND SEISMIC ANISOTROPY

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The recent development of portable short-period digital arrays in conjunction with the upgrading of existing permanent networks has significantly improved our possibilities to investigate the geotectonic settings of the upper mantle.
It is now commonly accepted that besides strong lateral velocity heterogeneities, upper mantle structures can be characterized by the amount and direction of seismic anisotropy. We demonstrate that the anisotropy deduced from Pn and S-like phases complement remarkably well isotropic tomographic studies, not only for mapping structural features within the lithosphere, but also for accessing the style of deformation at depth, one fundamental parameter for discussing the geodynamic evolution. Examples of applications of array studies in France include the RhineGraben area, the Pyrenean and Alps mountain ranges, the French Massif Central and most recently the Armorican Massif. All these target areas are remarkable tectonically active regions characterized either by volcanism, collision or extension. In this paper we shall present the latest results obtained from 2D- and 3D-imaging experiments for P- and S-wave velocities and anisotropy including petrological and geochemical constraints.

CADOMIAN TECTONICS IN NORTHERN BRITANNY: RESULTS FROM IMAGERY AND 3D MODELING AT A CRUSTAL SCALE.

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The Cadomian orogenic domain is the only outcropping area of the Late Proterozoic basement of NW Europe, preserved from later strong deformation. Following previous intense surface mapping and field studies, the ARMOR Project, set on within the frame of GéoFrance3D program, was devoted to the study at a crustal scale of the main Cadomian tectonics.
Prolonging to the south a previous marine deep seismic profile, combined surveys performed on land have included a deep seismic reflection, magnetotelluric soundings, detailed gravimetric profiling and further modeling in order to investigate the geometry of the main geological contacts along a single transect. The study of the tectonics and geometries at depth in other domains was based on gravity and magnetic maps analysis and modeling.
The 3D geometrical models built upon these various studies display the geometry of the main cadomian tectonic features. The tectonic planes appears to be steeply dipping in the uppermost crust and are then progressively flatenning down to at least 10 km deep. Taking in account the geophysical results, the 3D modeling and field evidence, Cadomian tectonics are best explained at a crustal scale as a large oblique strike slip thusting system.

3D IMAGING OF THE HERCYNIAN SUTURE IN THE FRENCH "MASSIF ARMORICAIN"

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The Armorican Massif (western France) is a part of the hercynian orogeny with its several phases of SE-NW compression from Devonian to Carboniferious time (400–300 Ma). The main tectonic features are the north- and south-armorican faults with WNW-ESE strike. The increased seismic activity in recent years along these faults has triggered some interesting questions: - Do the tectonic structures of the hercynian times still affect the whole of the lithosphere ? - Do they control the actual regional tectonic movements ? - What is the vertical extension of the deformations related to the hercynian range ? In order to sched light on these questions, we have installed a temporary seismological network in this area for 9 months. The network consisted of two approximatively 200 km long parallel profiles crossing the main faults approximatively perpendicular (N15E azimuth). Each profile consisted of 18 stations with a station spacing of 5 to 10 km and a distance between both profiles of about 30 to 40 km. the stations were equipped with either 1 s, 5 s and 2 broad band seismometers. Local regional and numerous teleseismic events were recorded resulting in a large and complementary data set (*Pn, P, PKP, S, SKS* ...). Data examples and very preliminary results (first step) of the work will be shown.

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3D MODELING OF THE ARGENTAT CRUSTAL ZONE (GÉOFRANCE 3D PROGRAM)

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In the French Massif Central, the 300+/- 30 Ma period is characterised by several economic mineral deposits (Au, U, W). 3D modeling of the South Limousin crustal block has been carried out, using the gOcad modeler, based on nine interpreted cross sections, geologic map, gravimetric and geochemical data (As). The coincidence of major tectonic units, As anomalies and Au indices points to the major role played by two features during As-Au rich fluid migration: the Argentat fault and the lower gneiss unit (LGI). However, this latter unit is not uniformly affected by these fluids. To the south (Tulle antiform), these anomalies are uncommon, while, to the north (Meuzac antiform), they spread toward the west to the St Yrieix gold mining district. To the north as well as to the south. the inversion of gravimetric data shows the presence of a pluton, about 3 to 5 km thick, which may have provoked fluid motions. The observed difference probably comes from the permeability of the two LGI zones, the northern zone be ing more fractured than the southern one. A global mechanism including thermicity and tectonics of this region has to be investigated in order to propose a P-T-t-X path compatible with geological constraints.

A DETAILED GRAVITY SURVEY IN CEVENNES (SOUTH-EAST MASSIF CENTRAL) : CONSTRAINTS ON THE 3-D CRUSTAL STRUCTURE

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We have carried out a detailed gravity survey in the framework of the GéoFrance 3D program. This survey allowed to fill one of the gaps in the existing gravity coverage over France. In most parts of the surveyed area we sampled one gravity measurement/km^2. The 1200 data points were measured using Scintrex CG3-M meters. Locations and altitudes were obtained by differential GPS. Altitudes of some IGN benchmarks were also measured using GPS in order to accurately determine the geoid anomaly. Inner zone terrain corrections were estimated on the field, and outer zones, up to to 167 km were computed using a DTM. The overall accuracy of the complete Bouguer anomaly ranges between 0.5 and 2 mGal depending upon the terrain roughness. The resulting Bouguer map highlights the N-S asymetric shape of the pluton inferred from surface geology and clearly shows the location of the plton's root. The homogeneity of the data set allows us to test several interpretation techniques including the fractal approach for density determination, Euler deconvolution and analytical signal methods. We present and discuss here some results ofthe analysis and modelling of the complete Bouguer anomaly in light of the geological observations.

DEEP AND SHALLOW STRUCTURE OF THE NW MEDITERRANEAN: NEW INSIGHTS ON THE LIGURIAN SEA AND MARGINS

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The NW Mediteranean has been formed by the counterclockwise rotation of the Corsica-Sardinia block away from Europe in the Late Oligocene-Early Miocene. Compilation of various and numerous existing geophysical data, reprocessing of gravity and magnetics, structral mapping from numerous recent MCS seismic profiles have provided much new details on the geometry of the margins structures. Steep and narrow margins of the Ligurian sea display strong differences compared with the Gulf of Lions and Western Sardinian margins where a wide continent-ocean transition domain exists. Although they appear relatively linear at a regional scale, investigation and mapping of structures of the Ligurian margins at different levels have revealed a close segmentation at a scale of a few tenths of kilometers. While general structure of the basin and margins was formed during the Ligurian sea opening, large post-rift volcanism, vertical movements and messinian erosion and very coarse sedimentation have played a significant role in the shaping of the present structures.

LOCAL EARTHQUAKE TOMOGRAPHY OF THE SOUTH-WESTERN ALPS (GÉOFRANCE 3D 1996 EXPERIMENT)

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A 6-month seismological experiment was conducted in 1996 in the southwestern Alps within the framework of the Géofrance 3D project (see companion paper by Fréchet et al.). The short interstation spacing (10 km) and the large number of local earthquakes recorded (more than 300) provide a unique opportunity to compute high-resolution 3D images of the crustal structure. We use the classical technique of Thurber (1983) to invert traveltimes of local events for *P*-wave velocities in a crustal block of size 160x160x20 km^3 centered at 44.5°N-7°E. Although resulting images are still preliminary, their most striking feature is the high-velocity anomaly associated with the Ivrea body. Between 1 and 6 km depth, it appears as a narrow (width smaller than 10 km) north–south–elongated high–velocity (6.5 to 7.2 km/s) structure. The anomaly extends northward with weaker amplitudes and a progressive shift to the east, following the general trend of the Bouguer gravity anomaly. Towards the south, it disappears suddenly below the northern limit of the surface exposure of the Argentera crystalline massif. At depths greater than 7–8 km, the high–velocity body widens while shifting 15 km to the east. The second most stable feature of the tomographic images is a low–velocity zone (4.5 to 4.8 km/s) visible at shallow depths ($\leq$ 8 km) beneath the front of the Digne nappes.

GEOLOGICAL, GEOPHYSICAL AND RADIOCHRONOLOGICAL INVESTIGATIONS IN THE FRENCH MASSIF CENTRAL. CONSEQUENCES ON THE MEGASTRUCTURE INTERPRETATIONS

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The variscan belt of Europe is a metallogenic province (W, Au, U) where the main mineralizing processes occured between 330 and 270 Ma. The French Massif Central is a case history for Paleozoic collision orogens and includes significant ore deposits. The origin and conditions of emplacement of the hydrothermal paleofield are used as markers of the late orogenic evolution of the variscan belt. The imaging of the upper crust (0-5km) is based on multidisciplinary modelling of the geometry of the main geological units and structures. The major thrust zones and gneissic units are well constrained by mapping and gravimetry field, locally by re-processed seismic profiles. The geometry and geochronology of the main transcurrent and extensional shear zones, granites and Carboniferous basins are used as markers of the transition from compressional to extensional tectonics which starts from 330 Ma. Their relationship with the mineralizing fluids and ore-deposit is a key for understanding the cause and the engine of the hydrothermal paleofield. The discovery in the Limousin of large structures acting as fluid channels is a first result which presumes of the connection of deep rooted faults with sources at depth, during the onset of extensional tectonics.

3D CRUSTAL STRUCTURE OF THE SWISS ALPS: LATERAL CHANGES IN SPACE AND TIME

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The European lower crust at the transition form the Eastern to the Western Alps displays a remarkeably regular structure. In contrast the lower crust of the dAdriatic palte changes along strike from east to west reflecting the transition within a stretched continental margin; in the east the lower crust forms a deep seated deformed wedge forced into the European plate, whereas in the west it remained near the surface after Mesozoic extension and associated uplift and now displays the effects of Alpine compression.
The upper crust's 3D geometry as imaged by the top surface of the pre-Triassic crystalline basement is a regular surface in a 1st order approximation only. Elongate basement uplifts with amplitudes exceeding 10 km are arranged en echelon along strike. The internal structures associated with these uplifts encompass fold and thrust structures that vary significantly along strike. A series of geologic profiles controlled by seismic data spaced at 50 km intervals reveal that individual, km-scale structures do not persist laterally. Cooling data suggest that the basement uplift formed in an irregular fashion, propagating along strike in time. Deformation sequences within individual cross sections in general propagate down and outward; thrust faults that extend into the foreland are responsible for a substantial part of the amplitudes of the basement uplifts.

3-D MANTLE TEMPERATURE AND DYNAMICS OF THE FRENCH MASSIF CENTRAL FROM INTEGRATED INTERPRETATION OF SEISMIC TOMOGRAPHY, MANTLE XENOLITHS AND SURFACE HEAT FLOW

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Teleseismic P-wave delay times, PT estimates from mantle xenoliths and surface heat flow in the French Massif Central are jointly interpreted in terms of 3-D mantle temperature distributions. The effects of anharmonicity and anelasticity on seismic velocities as well as effects of mineral reactions, composition and partial melt are considered in this interpretation.
The 3-D temperature distributions are used as input for modeling of mantle convection with temperature- and stress- dependant 3-D variable rheology. This allows to calculate a mantle contribution to the dynamic topography and geoid..
The teleseismic travel time delays, mantle xenolith data, surface heat flow as well as dynamic topography and geoid in the Massif Central can be explained by upper mantle temperature variations and associated buoyancy forces related to the interaction of the relatively small mantle plume with the lithosphere. The plume probably extends down to at least 300-400 km and has excess temperature of 150-200°C.. This model suggests an uplift of the thermal lithosphere-asthenosphere boundary to a depth of 65-70 km with a 50-70 km wide band of stronger lithospheric thinning which crosses Cenozoic volcanic fields and strikes parallel to the direction of maximal compression in the crust. We speculate that this plume is originated from instability of the hot mantle material pooled in the mantle transition zone provoked by the slab subducted beneath the Alps.

PRESENT-DAY STRESS REGIME WITHIN THE INNER WESTERN ALPS

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The Briangonnais seismic arc, located immediately to the East of the Penninic Front (PF) in the Internal Zones of the Western Alps, is the most active seismic zone in the French Alps. This seismotectonic study integrates precise location of the events within this zone, provided by the dense Sismalp and IGG permanent networks and the hyper-dense GioFrance 3D temporary network. Cross-sections show that this upper-crust seismicity is controlled by the PF. We computed about 80 reliable focal solutions allowing stress tensor inversions. Most mechanisms characterize normal faulting along fault planes subparallel to the PF, while the others characterize strike-slip motions, dextral along the same direction. This analysis points out that the stress regime East of the PF is globally extensive along an E-W axis, with some strike-slip component. Moreover, the seismicity of this area follows fairly well a large fault system developed between the Pelvoux, Argentera and Viso massifs, as a last deformation step in the structural history of the region. This system presents mainly two fault families. tangential and radial to the Alpine arc, which have been shown to work first as normal faults and then as transcurrent faults. As a whole, the seismicity appears in good agreement with the structural analysis of the late Alpine tectonics. Such an extension in the inner part of a collision belt asks for an adequate geodynamic model. We propose a model where the present-day stress regime is controlled by interactions between the counterclockwise rotation of the Apulia indenter and the behaviour of the European subducted slab.

3D GEOMETRIC AND GRAVITY MODELING OF THE CADOMIAN OROGENY (ARMOR Project)

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The Late Proterozoic orogenic structures of the Cadomian area of North Brittany (NW France) have been recently investigated through a number of geophysical operations and modeling. Based upon geological observations and in addition to magnetic analysis, seismic and magnetotelluric interpretation, 2.5D gravity models have been performed in order to constrain the varying structures between the different tectonic units of the Cadomian orogenic domain. From these profiles, automatic 3D volume reconstruction of geological objects have then been realized using Voronoi diagram method. Gravity contribution of this volume has been computed and compared to the observed Bouguer anomaly. When localised uncertainties appear, inversion method have been used on the close-up view and solutions were added for the automatic 3D volume reconstruction. By trial and error, the 3D geometric model has been improved in order to have a gravity response close to the observed anomaly. This approach is powerfull to solve complex structure geometry. Tectonic implications of the resulted 3D geometry are discussed.

3D GRAVITY MODELLING OF THE SOUTH LIMOUSIN : INSIGHTS OF THE GRAVITY-GEOCHEMISTRY ANOMALY RELATIONSHIPS

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This study, set on within the frame of GÚoFrance3D program, is focussed on the gravity-geochemistry relationship for metallogenic implication understanding. Eight profiles were extracted perpendicular to the main structures from the Bouguer anomaly map. 2.5D gravity modelling have been performed constrained by geological observations and density measurements. A 3D geometric model based on these profiles has been realised using an automatic method (Voronoi diagrams). The gravity contribution of this model was computed and compared to the observed Bouguer anomaly. All gravity discrepancies between the calculated and the observed Bouguer anomaly map are located along geochemistry anomalies. Metallogenic implications are discussed. In particular, presence of dissemination of sulphide in relation to geochimistry anomalies, appears as the best hypothesis for explaining heavy gravity anomaly. Forward gravity modelling allows to evaluate the depth of these anomalous domains.

MULTISCALE GLOBAL 3D INVERSION ON GRANITIC PLUTONS IN THE MASSIF CENTRAL FRANCE

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Granitic intrusions commonly show negative gravity anomalies due to their lighter density, the 3D gravity inversion of which reveal their deep organization. When realized over a single massif, it provides the place of magma feeders. At larger scale, inversion looses resolution on the internal organization of individual plutons, but shows how massifs are imbricated. In the French Massif Central, most of the granites excepted those of Saint-Sylvestre and La Marche, in the north, are not connected between them and behave as independent plutons. They show no definite structural trend. A specific gravity low, trending EW appears close to the zone of gold mineralization of Saint Yriex. The anomaly has been modelled at various scales from 2 to a 0.3 km mesh size. The bulk trend of the negative anomaly suggests that a light source body exists at depth, which is not only a low in the gneissic unit. At finer scale, two gravity lows suggest two separate bodies, one trending EW, another to the west with trend N120. The fine scale interpretation shows that only the eastern unit corresponds to a light source trending EW. It could represent a granite, not very thick (2-5km), below the mineralized zone.

SE17 Dynamics of plate boundaries

01 Geodynamics of collision belts: stacking and exhumation processes

Convener: Kilias, A.
Co-Convener: Ring, U.

THE «STACK OF NAPPES» IN WESTERN CRETE

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Previous authors described in the area around Chania, Crete, a stack of three nappes on the basis of the position and colour of the various rock units. The contact of these units can rarely be seen in the field but where it can be seen, it is transitional. The previous authors ignored the existence of important structures which result from the numerous high-angle faults of small dip-slip displacement, which occur in the area. Erosion of these structures, results in the occurrence of older rocks in higher elevations than the younger ones. The unsuspected geologist ignores these structures, and in order to justify the juxtaposition of various rock types, he has to invoke nappes or large scale unconformities. The consideration of the movements on these faults, simplifies the structure of the area and it needs not to invoke nappes or large scale unconformities.

WHEN, HOW AND WHY THE SOUTH CARPATHIANS LOOPED AROUND THE MOESIAN PLATFORM?

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If these are old questions for romanian geologists, in the nineties groups from Tübingen, Salzburg, Amsterdam, Basel, Paris and Bucharest tried to give more documented answers using modern structural analysis, Ar-Ar dating and information obtained in paleomagnetic laboratories of Budapest, Bucharest and Köln universities.

WHEN is debated between Late Cretaceous (Salzburg), Eocene (Basel) and Middle Miocene to Pliocene (Tübingen); 70-80 Ma K-Ar and Ar-Ar ages of mylonites give maximal values and 15 Ma K-Ar age of the oldest Neogene magmatic rocks clock-wise rotated in the Apuseni Mountains give a minimal value.

HOW is meaning if the necessary orogen-parallel elongation took place in brittle conditions, along major strike-slip lineaments (Tübingen), or in ductile conditions, in large shear belts (Salzburg, Basel). In fact both happened, Latest Cretaceous to Eocene mylonites being cut by major dextral strike-slip Oligocene to Miocene faults.

WHY is now generally considered to be the effect of counteracting westward-directed corner effect of the Moesian Platform and estward-directed escape of clock-wise rotating Apuseni Mountains, the easternmost part of the Pre-Apulian Block.

A major discovery of the last years is the **metamorphic core complex** nature of the northern and eastern parts of the **Danubian Window**, recording Alpine low-grade metamorphism and outcropping below low-angle normal faults bordering it with the overlying Getic-Supragetic nappes, which do not shaw Alpine regional metamorphism.

THE TECTONOTYPE OF PALEOLATERAL STRUCTURES SERIES OF JURASSIC-NEOCOMIAN SIBERIA CONVERGENT MARGIN (the Taigonos peninsula, NE of Russia)

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The Taigonos peninsula structures is the part of the large Neocomian thrust-fold belt. Its consist of suprasubduction volcanic belt (SVB) and paleoaccretionary wedge (PAW) composite terranes. I. SVB from N to S include: 1) AR-PR metamorphic continental basement, divided from South by high-strain shear zone with 72.4-91.7 ma.(Ar-Ar) metamorphism; 2) P-J marine and K1 and Pg continental volcano-sedimentary rocks (the effusives are mostly suprasubduction origin); 3) J marine and K1 continental volcano-terrigenous rocks; 4) shelf carbonate-terrigenous C and suprasubduction and rifting origin P-J volcanogenic rocks, divided from S by granitic plutons belt (103 ma.). II. PAW consist of some thrust-: PZ and MZ oceanic and suprasubdaction ophiolites sheets (the inverse movement metamorphism is 130 ma.), olystostromes and turbidites of fore arc region. We shall discuses the problems of structural evolution, stages of magmatism and metamorphism of Taigonos as a part of Eastern Siberia convergent margin.

GEODYNAMIC EVOLUTION OF THE NORTHERN TYRRHENIAN BASIN FROM ^{39}AR/^{40}AR AGES ON MICAS ALONG A TRANSECT FROM CORSICA TO TUSCANY.

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We have undertaken a study of a transect from the alpine Corsica to Tuscany in order to understand the mechanism of the spatial transition from frontal compression to back arc extension in the Northern Tyrrhenian Bassin. The structural, petrological and ^{39}Ar/^{40}Ar data obtained both in Corsica and Tuscany suggest that exhumation/cooling of the HP units was syn-collisional and driven by gravitational collapse restricted to the upper part of the accretionary wedge. P-T-t paths imply that a cool geotherm was maintained during the whole exhumation process. The present HT-LP gradient occured later, around 15 Ma in Corsica, and migrated easternwards with the opening of the Tyrrhenian Sea. The migration process is partly a consequence of the rollback of the subducting slab, true for oceanic subduction as well as for continental subduction. Gravitational collapse decreases with time because of the reduction of crustal thickness. As for the post-collisional extension, it can be due to the rollback that increases with the length of the slab.

SYN-COLLISIONAL EXHUMATION OF HP-LT ROCKS IN THE CALABRIA-LUCANIA BORDERLAND AREA (SOUTHERN ITALY)

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In the Italian regions of northern Calabria and southern Lucania, blueschist-facies rocks of oceanic derivation are tectonically interposed between greenschist-facies to non-metamorphic carbonates of passive margin origin (below) and crystalline basement nappes of continental crust derivation representing remnants of the overriding plate. Structural, petrological and radiometric data from northern Calabria and southern Lucania allowed us to unravel a complex deformation history associated with the subduction, collisional, and post-collisional evolution of two suture zones of different age. The structural evolution of the collisional stacking wedges is mainly recorded by the development of tectonic pressure-break contacts of both "normal-" and "reverse-sense" types, the former showing relatively low-pressure rocks overlying high-pressure ones, and the latter displaying an opposite relationship. Our results suggest that exhumation of relatively HP-LT rocks occurred within the collisional belt as a result of both uplift and erosion associated with crustal-scale thrusting, and of syn-collisional extension driven by large-scale duplexing at depth.

Unusual HT quartz c-axis fabric developed in the quartz-mylonites of the Espinho Formation (Ossa-Morena Zone, NW Portugal)

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The Espinho-Albergaria sector (Ossa-Morena Zone, Iberian Variscan Belt, NW Portugal) is a part of a narrow strip, NW-SE, of a proterozoic metamorphic belt located alongside the major shear zone Porto-Albergaria-Tomar.

Microstructural studies were carried out on the quartz-mylonite of the Espinho Formation (garnet-staurolite micaschist and garnet quartzite). The quartz-mylonite is located near the Lourosa overthrust (D3 Variscan fold phase) and contains S-type and L-S type mylonites developed under HT metamorphic conditions. These rocks present a penetrative mylonitic foliation and well-developed stretching lineation with kinematics criteria deduced from the geometry of polycrystalline quartz aggregates, σ type porphyroclasts, S-C planes and extensional crenulation cleavage. These criteria indicating a top towards NNW sense of shear movement during the early Variscan fold phases.

It is the first time in non-migmatized metasedimentary rocks naturally deformed that quartz c-axis fabrics show clear evidences of HT conditions during their development. Theses evidences are: i) a dominant c-axis maximum close of the X direction, that suggest intracrystaline plasticity by the activation of the prismatic slip planes over the c direction; ii) the occurrence of elongate shaped garnets plastic strained parallel to the stretching lineation.

Metamorphic mineral assemblage, with white mica+staurolite+garnet±sillimanite allow to define the amphibolite facies of high temperature zone (around 600° C) during the mylonitization. On relation with this process, non-coaxial deformation with monoclinic symmetry fabrics are found and we also noted the occurrence of rhombic and prismatic slip system over <a> direction that together with minor c-axis circle maximum, with an semi-opened average angle of 45°, allow the reconstruction of skeletal type I crossed girdles.

The regional implications coming out from these results will be discussed in the context of the Espinho-Albergaria metamorphic belt.

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NON-EXTENSIONAL PALEOZOIC HIGH-P ROCK EXHUMATION IN THE SOUTHERN URALS

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The Southern Urals, the only Paleozoic orogen that preserved its collisional architecture and lacks late-orogenic extension, present an orogenic wedge thrust westward upon the subducted, former East European continental margin. The N-S trending antiformal stack exhibits major tectonic contacts with discontinously decreasing metamorphic conditions from bottom to top. The Maksyutov high-P complex in the core is composed of two tectono-metamorphic units, with well-preserved blueschists and eclogites in the lower Unit (min. P 12 kbar and peak T ~550 °C) and the overlying Unit with lawsonite-bearing assemblages (min. P< 8 kbar and T < 450 °C). Both units exhibit a composite foliation S1 affected by NW-vergent F2 folds trending obliquely NE-SW. They record progressive NW-directed shearing under prograde metamorphic conditions during eastward subduction and oblique NW-SE plate convergence at ~375 Ma. The units were then tectonically juxtaposed by a ductile, top-to-the-NE extensional shear zone with a retrograde greenschist facies overprint. Subsequent exhumation was accomodated by the Main Uralian Thrust at the base of the wedge. The E-dipping Main Uralian Normal Fault cross-cuts the metamorphic footwall and developed during subduction compensating crustal thickening and the exhumation of high-P rocks. Geologic investigations and reflection seismics (URSEIS' 95) emphasize an evolution integrating subduction and basal accretion of high-P rocks during sinistral oblique thrusting along the Main Uralian Thrust and coeval normal-faulting along the Main Uralian Normal Fault.

GEODYNAMIC MODELS OF CRUSTAL-SCALE EPISODIC TECTONIC ACCRETION IN SUBDUCTION ZONES

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At large (crustal) scales, accretion of material at convergent margins may occur either as a continuous, quasi-steady-state process, or episodically by incorporation of large blocks of incoming material. We investigate the dynamics of crustal-scale episodic accretion at convergent margins using a finite-element model of subduction that incorporates effects from flexure, subduction loading, density contrasts, material heterogeneities and layerings. The model is used to assess the influence of these parameters on the discrete transferral of units from the lower to the upper plate during subduction. Primary controls are spatial variations in buoyancy and material strength (for example, caused by a changing thermal structure of subducting lithosphere and/or attempted subduction of small crustal blocks); interaction between well-attached basement blocks and overlying, detachable sediments; and spatial changes in depth of material layerings. We show that the accretion of small continental terranes to a subduction zone can cause crustal-scale fold nappes and thrusts to develop, with accompanying tectonic underplating (in the case where lateral continuity of oceanic sediments is maintained) and/or frontal accretion (where sediment continuity is disrupted). The model results may aid interpretation of real examples of episodic accretion, for example the emplacement of the Penninic nappe stack during the subduction phase of the Central Alps.

MOUNTAIN BUILDING AND THE ROLE OF PHASE TRANSITIONS

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A simple, univariant phase transition for minerals at lower crustal scale is studied. The phase transition is modelled including: *i)* the chemical potential; *ii)* a kinetic term describing the thermally activated diffusion of grains; *iii)* a simplified effect of the nucleation process, according to which the evolution of the phase follows an approximated the Avrami's rate equation. Different activation energies for the prograde and retrograde reactions allow us to study the process of formation and preservation of high pressure phases. The phase transition model may be coupled with thermal and thermo-mechanical models that represent typical processes in collisional environment. The phase transition to a denser phase may occur when the displacement of cold material at depth is fast enough to preserve its thermal anomaly. Afterwards, the re-heating associated to the thermal equilibration favours the retrograde reaction. Our results suggest that phase transitions may play a major role in the evolution of topography, thermal profile and mineralogy.

CRETACEOUS SYN-METAMORPHIC DEFORMATION OF THE SERBOMACEDONIAN METAMORPHIC PROVINCE (N. GREECE)

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Detailed study of the predominant D_{SRB} ductile deformation of the Serbomacedonian (SRB) metamorphic rocks in northeastern Greece, based on field and micro observations, kinematic and strain analysis as well as thermobarometric estimates, give new evidence about the tectonometamorphic history of the SRB mass and its significance in the structural evolution of the southern Balkan peninsula. Correlation between published geochronological data and D_{SRB} deformation allows us to date the D_{SRB} event as a Cretaceous age, ductile event. A main top-to ENE to ESE ductile flow and a locally subordinate component of WSW to WNW antithetic sense of movement characterize the D_{SRB} event. Strain pattern analysis showed in general a flattening type of the finite strain ellipsoid with an important pure shear value. The positions of all possible equilibria implied by the critical syn-D_{SRB} mineral paragenesis in metapelitic as well as in amphibolitic rocks are also computed in P-T-X(CO_2) activity space by the TWQ program. The estimated values of the metamorphic P-T conditions range from 5 to 9 kbar for the pressure and 440 to 550°C for the temperature. D_{SRB} is associated with subhorizontal crustal stretching and unroofing of the SRB mass. It took place behind the Balkan thrust belt at the northern Rhodope boarder, during the Cretaceous continent to continent collision between the Rhodope (SRB included) and Moesian fragments.

NEOGENE DENUDATION OF THE MENDERES MASSIF, TURKEY

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Many Tertiary Alpine orogenic belts in the Mediterranean region have undergone rapid denudation of rocks from the mid and lower crust to the surface, often in association with normal faulting at a late stage in their evolution. To understand this phenomena in the Menderes Massif of SW Turkey we aim to combine fission track analysis with structural studies to obtain quantitative estimates of cooling, denudation, and strain rates so as to discriminate between erosional and extensional denudation, quantify their respective contribution to the orogenic unroofing history and place time constraints on their action. Preliminary results from the apatite fission track study has revealed that this elongate culmination of metamorphic rocks experienced a regionally varied cooling history during the Neogene, which by inference indicates a complex denudation history. Rapid cooling from temperatures >120°C to <60°C during the Aquatanian (~22±1 Ma), particularly in the Cine submassif but possibly throughout the Menderes, was followed by variable rate cooling over the same temperature interval in other sections of the massif throughout the Miocene with final cooling in the northern Ödemis submassif during the Pliocene. An initial interpretation of the results suggests that the early cooling was related to tectonic denudation and was followed by variable erosive denudation, controlled in part by the development of the east-west trending grabens that now bisect the massif.

THE EARLY-ALPINE TECTONOMETAMORPHIC HISTORY OF THE MENDERES MASSIF, SW TURKEY: IMPLICATIONS FOR THE EVOLUTION OF THE EASTERN MEDITERRANEAN

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The Menders Massif of southwestern Turkey is commonly viewed as the eastern continuation of the Attic-Cycladic Massif in the Aegean Sea. However, in contrast to the southward propagation of orogenesis in the Attic-Cyladic Massif with its Variscan basement, the structure of the Menderes Massif consists of a north-vergent nappe stack comprising a Pan-African basement sandwiched between a lower and an upper sedimentary unit. The lower sedimentary unit can be correlated with the Cycladic blueschist unit; however, most of the lower sedimentary unit in the Menderes Massif lacks a high-pressure overprint and its Variscan basement is not exposed. Sedimentation in the upper sedimentary unit probably commenced in the Late Paleozoic and lasted until the Cretaceous whereas deposition in the upper sedimentary unit commenced already in the Precambrian and also lasted at least until the Cretaceous. Structural and metamorphic work reveals an early deformational event associated with top-N thrusting during prograde amphibolite-facies metamorphism that caused stacking within the basement unit. Subsequentely, the basement was thrust onto the greenschist-facies lower sedimentary unit. Alpine thrusting in the Menderes Massif depicts a conspicuous progression in space and time from south to north. Our work indicates that the architecture and the northward progradation of orogenesis in the Menderes Massif is different to the structure and the tectonic evolution of the Attic-Cycladic Massif. To account for this discrepancy, we propose that a N-trending dislocation zone separated both massifs at least periodically during the Alpine orogeny.

HIGH PRESSURE METAMORPHISM IN THE AEGEAN REGION: WHEN DID IT HAPPEN AND WHAT HAPPENED NEXT ?

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Amongst the lithologies, which are currently exposed in the Aegean region, metamorphic rock sequences occur, which are known to have been exposed to PT conditions which indicate metamorphism at middle to lower crustal levels. Investigation of the metamorphic sequences covering different parts of the Alpine pressure-temperature spectrum in domains around the Aegean Sea, allows to establish local tectonic histories, which, after comparison of the timing and kinematics between the different domains, are used to differentiate into local and regional tectonic events and their characteristics. Ultimately the exact timing of the main regional tectonic episodes in the Aegean region will serve to quantify tectonic models of the circum Aegean region and/or the Mediterranean as a whole.
Ductile deformational structures which formed in the metamorphic sequences during the Alpine and post-Alpine tectonic events have been localized in the field and their kinematic characteristics have been investigated by applying integrated structural and metamorphic investigations and $^{40}Ar/^{39}Ar$ laserprobe age dating experiments.
By this approach we have been able to obtain a continuous record of Alpine tectonic events in the Aegean region, which concerns the whole timespan, starting from the onset of high pressure metamorphism in the Cretaceous, until the episodes of ductile deformation, related to the exhumation of the metamorphic domains, which are now documented until as recently as ca 7 Ma ago.

NAPPE STACKING AND EXHUMATION OF HIGH-PRESSURE ROCKS DURING CONTINENT COLLISION: A VARISCAN SCENARIO FROM THE WESTERN ERZGEBIRGE

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The history of the western Erzgebirge (central European Variscides) appears to be part of a larger-scale late-Variscan continent-collision scenario. The deformation structures reflect a two-phase kinematic history with an intensive subhorizontal compression and a subsequent relatively weak subhorizontal extension. The continental crust of an upper plate was thrust from ESE to WNW over the continental crust of a subducting plate. During the early stage of collision large and thin crustal slices were detached from different positions of the plates and brought to partly different depths. Subsequently these slices were back-thrust by the advancing plate and imbricated with other nearly exhumed slices. This led locally to an inversion of the older (and higher) metamorphism. Simultaneously, only the upper parts of the doubled continental crust were thinned by predominantly horizontal extension. Most probably, the boundary between the upper and the lower plate is represented by a lithologically variable zone which contains lenses of eclogites, high-pressure granulites and lower-metamorphic metapelites with relics of sedimentary structures.

THERMAL-MECHANICAL MODELS OF EVOLUTION OF LAYERED LITHOSPHERE IN COLLISIONAL BELTS

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Thermal-mechanical model of continental collision including lower crustal flow is developed and applied to the modelling of the formation of Lapland-Kola collisional belt (northern Baltic Shield) and the Kapuskasing structural zone (the Superior Province Canadian Shield). The temperature, velocity and stress distribution are calculated based on 2-D model of collision simulated by shortening event which led to overthrusting in the brittle upper crust and the formation of the thickened lower crust by ductile deformation. Finite-element 2-D modelling was used to examine the conditions under which ductile flow of the rheologically layered lower crust and upper mantle can produce the structure with crustal roots and surface uplift as a result of shortening, loading and erosion. The numerical calculations show that viscous flow at the depth of the lower crust and upthrusting of the brittle upper crust can be feasible mechanism, leading to the structural formation with crustal roots. The amount of crustal thickening and the tectonic stresses required to sustain shortening and overthrusting constrain the range of viscosity values for the lower crust and upper mantle. The deformation histories of the investigated regions that were shortened during the compression show some differences.

THE EVOLUTION OF THE ADULA NAPPE (SWITZERLAND): NEW DATA AND THE CONSEQUENCES FOR THE EVOLUTION OF THE PENNINIC NAPPE EDIFICE

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The Adula nappe, part of the Penninic nappe pile, consists of an upper unit characterized by relics of a HP-event, and a lower unit free of HP-relics. The upper unit formed an extensional allochthon located south of the southern margin of Europe, whereas the lower unit belonged to an internal part of the same continent. The closing of the Valais trough resulted in subduction of the extensional allochthon under increasing PT conditions (D1). Subduction culminated under eclogite facies conditions (600 °C, 2.5 GPa) during a second deformation phase (D2). Exhumation from about 80 km to 40-30 km followed immediately, leading to amphibolite facies conditions (640 °C, 0.7 GPa) and the development of the predominant fabrics observed today (D3). Exhumation is related to extensional movements and extrusion due to compression in the higher and deeper levels of the forming orogen, respectively. Contemporaneously to the exhumation of the upper unit, the lower unit experienced a prograde metamorphic evolution caused by ongoing compression culminating under amphibolite facies conditions (670 °C, 0.8 GPa) during D2. Underthrusting of the lower underneath the exhumed upper unit is related to shortening under low-grade conditions within the growing orogen.

NON-LITHOSTATIC PRESSURE DURING CONTINENTAL SHORTENING

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This study investigated whether, in a compressive tectonic setting, the pressure recorded by rocks could significantly exceed the lithostatic pressure. While most of the previous works on overpressure focused on micro- to macroscopic scale variations in pressure that can be ascribed to heterogeneities, this study focused on variations on a larger scale achieved by the response of a homogeneously layered lithosphere to applied stresses. A 2D finite element code coupling mechanical and thermal calculations was used. The rheology assumed was Mohr-Coulomb plasticity or thermally activated power-law creep, depending on whether a yield strength criterion was fulfilled. The results indicated that in the regions deforming plastically (upper crust and uppermost mantle) the pressure reached values equivalent to twice the lithostatic pressure. In the viscously relaxed layers (lower crust and lower upper-mantle) no further increase with respect to a lithostatic gradient was attained but pressures significantly exceeding lithostatic values were maintained. In these layers features observed in high-pressure terrains, such as inverted pressure gradients and extremely high-pressure gradients (2kbar/km) were achieved. High pressure gradients, such as those described, have several implications: 1) exhumation of high-pressure rocks would be simplified. 2) high p/T ratios can be achieved in continental collision settings. 3) the fact that rocks could experience increase in pressure without being buried decouples metamorphism from continental thickening.

PROTEROZOIC CRUSTAL KINEMATICS AND EXHUMATION OF DEEP-CRUSTAL ROCKS IN THE SOUTHERN SUPERIOR PROVINCE

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Structural analysis, regional tectonometamorphic correlation and a crude palinspastic reconstruction suggest that Paleoproterozoic intracontinental deformation in the Archean Superior Province was strongly controlled by tectonism at its southern margin, i.e. the Penokean Orogen. Structures in the Lake Huron portion of the orogen formed by dextral transpression during the Blezardian (2.4 - 2.2 Ga) and the Penokean (1.9 - 1.8 Ga) tectonic pulses. Deformation occurred under medium-grade metamorphic conditions and was accompanied by local granitoid magmatism. Horizontal strike shear was most likely imposed by margin-parallel translation of Proterozoic magmatic arc terranes which eventually collided with the Superior Province in the Lake Superior area between 1.89 and 1.83 Ga. In this area, collision led to crustal thickening, widespread magmatism, deformation under high-grade metamorphic conditions and "rigid-body" indentation of the Superior Province. Indentation provides a plausible explanation for (1) distortion of the radial Matachewan dike swarm in the southern Superior Province, (2) lateral eastward extrusion of Archean crust and (3) localized exhumation of deep-crustal rocks by thrusting in the Kapuskasing structural zone which constrained eastward extruding Archean rocks.

DID EROSION MAINLY EXHUME THE AEGEAN BLUESCHISTS?

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I quantify, to a first order, the amounts which horizontal extension, vertical ductile thinning and erosion contributed to the ~45 km of exhumation of the blueschists exposed on Samos Island, Greece, and Dilek Peninsula, Turkey. Exhumation of the Aegean blueschists is commonly thought to be chiefly due to horizontal extension. The onset of extension, however, postdates the Eocene peak of high-pressure metamorphism considerably and commenced when the rocks had made about two thirds of their way back to the Earth's surface. Eocene to Oligocene crustal shortening caused thrusting of the blueschists onto a low-grade foreland unit. At the same time, the presumable cover of the blueschists was also considerably shortened, indicating that exhumation of the blueschists at this stage was not aided by horizontal extension at any crustal level. I estimate, assuming steady-state flow, a proportional strain-rate law and isochoric deformation, that vertical ductile thinning associated with a subhorizontal foliation contributed ~9-10 km of exhumation of the blueschists during thrusting. The remaining ~20 km must have been achieved by erosion at an inferred average rate of <0.6 mm/a. Horizontal extension in the study area started in the Middle Miocene and continued intermittently until the present. The throw on extensional faults during this phase accounts for ~6-8 km of blueschist exhumation. Ductile thinning contributed another ~3-4 km. Present-day erosion rates are on the order of 0.2 mm/a, but have probably been higher at the onset of crustal extension. Extrapolating this rate back into the Middle Miocene yields a minimum of 3 km of erosional exhumation since then. The results suggest that erosion was the major agent of exhumation of the studied blueschists.

THE LIFE CYCLE OF THE EAST CARPATHIAN OROGENIC WEDGE

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The East Carpathian fold-and-thrust belt in Romania is studied by an integrated approach based on theoretical orogenic wedge models, structural and morphological field studies and an extensive fission track analysis. As a result the orogen can be divided in a three step evolution which is associated with major changes in the regional geology and geomorphology. In first instance (from 21-15 Ma) thrusts are stacked in a wedge that remains below sealevel. FT analyses record no erosion during this period. A second period follows from 15-10 Ma which is characterised by dramatic changes. Erosion rates rapidly accelerate from practically 0 to 0.5 mm/yr indicating that the wedge emerged above sealevel. It coincides with a climax in deformation and rapid subsidence of foreland molasse basins which are filled with clastics shed from the orogen. The changes are attributed to the arrival of the European continental margin in the subduction zone which causes a reorganisation of the deforming wedge. A period of steady state follows from 10-5 Ma until plate convergence ceases. A total of 4 km of material has been eroded thus far. A calculated mass balance suggest that the orogen is in a destructive phase during the Pliocene, marking the third evolutionary stage of the orogen. The region is uplifted due to erosion (1.5 km) and isostatic response. A three dimensional isostatic and flexural numerical simulation of the Romanian Carpathian region confirms the three step evolution of the Carpathian orogen both in a qualitative and a quantitative way and is consistent with the erosion estimates based on fission track analysis.

MIOCENE HIGH-PRESSURE METAMORPHIC ROCKS OF CRETE, GREECE: RAPID EXHUMATION BY BUOYANT ESCAPE.

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The Tertiary nappe pile of Crete, Greece comprises two main rock groups that were juxtaposed by extensional detachment during the Miocene. Detailed pressure, temperature and structural histories of HP-LT metamorphic rocks in the lower plate to detachment reveal that these rocks were subducted, subjected to pervasive deformation and metamorphism only at their depth of maximum burial (30-35 km, 300-400°C) between ~24 and 19 Ma and subsequently exhumed to less than 10 km and 300°C at rates ≥3.5 km/my before ~19 Ma. Microstructural analysis reveals that deformation during exhumation was localised along the extensional detachment that tectonically denuded these rocks with the bulk of the rocks of the lower plate being exhumed as a coherent block. In contrast, fission track data from the rocks of the upper plate show that they have remained in the upper 4 km of the crust since at least the Eocene. This reveals that tectonic denudation contributed 85 to 90% to the total exhumation of the HP-LT lower plate rocks. After cessation of movement along the main extensional detachment, both the upper and lower plates of the Cretan nappe pile were subjected to a phase of brittle extension and minor denudation at ~15 Ma. A tectonic model is proposed that requires continuous subduction retreat since at least the Eocene. Exhumation of the HP-LT rocks of Crete is driven by positive buoyancy of the subducted continental crust following slab breakoff. This allows the subducted microcontinent to return to the surface by entering the space created by renewed subduction retreat. We term this process buoyant escape.

THE REFRACTION SEISMIC EXPERIMENT GRANU95 - RESULTS AND CORRELATIONS WITH REFLECTION PROFILINGS

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The refraction seismic experiment GRANU95 was carried out in the Saxothuringian belt which is situated on the N-flank of the Variscan orogenic collage. The crosspoint of two perpendicular profiles was centered at the exposed Saxonian Granulite Massif (SE-Germany), a major exposure of lower crustal material. By using ray-tracing technique for the wide-angle P-wave seismic data and FD first arrival modelling for the Pg- and Ps-phases the interpretation led to a four layer model. Main features of the model are high velocities (6.3-6.6 km/s) at shallow depth (2-4 km) and velocities of 7 km/s, defining a prominent high velocity layer in the lower crust (22-24 km). The crust-mantle boundary, without any remarkable undulation, lies at about 30-31 km. The shallow high velocities with strong lateral variations correlate well in depth with highly reflective zones which were observed on several seismic reflection lines at their intersection with and in the surrounding of both seismic refraction lines. First results from S-wave modelling will be presented as well.

GEOMETRY AND KINEMATICS OF THE POST-METAMORPHIC THRUST SYSTEM IN THE CIRCUM RHODOPE BELT (CRB) AT THE WESTERN MARGIN OF THE HELLENIC HINTERLAND (GREECE)

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The complicated NW-SE trending Thrust System in the Circum Rhodope Belt (CRBTS) at the western margin of the Serbomacedonian massif that overthrusts towards SW the old ophiolitic suture of Axios zone is a main structural feature related to the Hellenic hinterland in Central Macedonia. The CRBTS comprises post-metamorphic (post-Eocene) thrust sheets resembling an antiformal stack geometry and a mainly SWward (N40°-70°) transport direction. At least three thrust sheets of the Serbomacedonian basement are recognized within the CRBTS. In between the thrust sheets, relatively older, SW-verging asymmetric folds associated with axial crenulation cleavage reveal similar kinematic symmetry with the thrusts. The whole thrust system is bounded from the Serbomacedonian massif by a steep arcuate, NW-SE trending fault zone that is characterized by a right lateral reverse oblique fault geometry and is related to the CRBTS. Relatively younger NE-directed back-thrusts rooted from this fault zone, locally emplaced the CRB rocks onto the Serbomacedonian massif. WNW-ESE to E-W faults and N-S to NNE-SSW faults usually forming oblique or/and lateral ramps to the main frontal thrusts of the CRBTS, indicate left- and right-lateral strike slip movements respectively. Orogen parallel lateral extrusion takes place locally between the conjugate sets of the strike-slip faults. Transpression is acknowledged as the main deformation mechanism of the CRBTS. Finally, we attempt to figure out the possible architecture pattern and geometry of the CRBTS through balanced cross-sections.

TECTONIC JUXTAPOSITION OF OCEANIC COMPLEXES ALONG THE NORTHEASTERN ASIAN CONVERGENT BOUNDARY IN THE LATE MESOZOIC

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In the Late Jurassic–Early Cretaceous, the convergent boundary between Asia and NW Pacific was marked by the extended Uda–Murgal island-arc system. The frontal zone of the arc displays ophiolitic terranes and offscraped oceanic fragments of various ages (Paleozoic, Triassic, Jurassic, and Early Cretaceous) and origins derived from the Paleo-Pacific crust. The accretion of these complexes involved tectonic stacking and formation of duplexes leading to drastic crustal thickening (vertical accretion). This resulted in thrust packages composed of oceanic complexes and in structured mélanges made up of individual mappable sheets of variably aged ophiolites. For example, Kuyul serpentinite melange combines the tectonic sheets of oceanic and suprasubduction ophiolite. The accretion was accompanied by strike-slip deformations and exhumation of subduction-related metamorphic complexes.

BLISTERS OF HOT MIDDLE CRUST IN THE NORTH AEGEAN EXTENSIONAL REGION

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At the western extremity of the North Anatolian Transfer Fault (North Aegean), several gneiss domes occur, which form prominent topographic rises and coincide with pronounced positive Bouguer anomalies. The gneiss dome of Thasos Island delineates the following characteristic features:

There is a distinct gap in time of about 8-10 Ma between (i) onset of plastic thinning of the middle crust (ca.6 kbar, 550°C) and exhumation along a first normal detachment, and (ii) ultramylonitisation, doming and exhumation of the deeper and hotter parts (ca. 8 kbar, 650°C) along a second detachment system. Translation along the second detachment determined updoming, surface uplift, and local formation of a steep topographic height, and also simultanous subsidence and basin formation in the surrounding of the dome. The second detachment is underlayn by a strong positive Bouguer anomaly of about 70 mgal (Memou et al 1985), which may be interpreted as a result of a mafic magma bubble or of upwelling of a hot mantle. This may provide a local upward pushing force and probably also cause heating of the deeper parts during plastic updoming (blistering). Similar relationships between topographic rises and basin formation (that is erosion and deposition) with deeper lithosperic structures can be supposed for the domes of Mount Athos, Pangeon and elsewhere.

Ref.: Memou,T., Kalegeropoulos, G, Skiani, G., 1985. IGME report, Athens.

SE17

GEODYNAMICS OF THE WESTERN PART OF MONGOLIA-OKHOTSK COLLISION BELT: STACKING AND EXHUMATION

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After the first episode of collision between Siberia and Mongolia, that occurred prior to the earliest Permian in the region of Khangay (Central Mongolia), the former continent was turned about 120^0 counter-clockwise with respect to the latter one, and the two still were separated by the Mongolia-Okhotsk ocean, an enormous gulf of the Pacific. According to geological and paleomagnetic evidence, complete suturing occurred at the Early / Middle Jurassic boundary as a result of clockwise rotation of Siberia. In East Siberia, collision involved a third element, the Onon island-arc terrane, that was squeezed between the two colliding continents.
After collision, sequences related to the active continental margin of Siberia and to the Onon island arc thrust over the passive margin of Mongolia. Middle and Late Jurassic thrusting and associated magmatism caused considerable thickening of the crust and uplifting in the south-eastern Siberia. At present the remnants of the uplift constitute an echelon of mountain districts of Khentey, Dauria and Olekma Stanovik. In the Early Cretaceous, the collisional uplift collapsed whereby thrusts transformed into low-angle normal faults, movements on which led to exhumation of metamorphic core complexes. Inversion of magnetic anomalies, produced by gneissic granitoids from the core complexes, imaged their geometry and thus enabled rough estimates of the amount of displacement related to the Early Cretaceous rifting.

SE17 Dynamics of plate boundaries

02 Active deformation along plate boundaries: measurements and models

Convener: Calais, E.
Co-Convener: Wdowinski, S.

RECENT CRUSTAL DYNAMICS IN THE AZORES ARCHIPELAGO DERIVED FROM REPEATED GPS OBSERVATIONS

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In the scope of project TANGO (TransAtlantic Network for Geodynamics and Oceanography), periodic GPS observations have been made in the area of Azores Triple Junction. From 1988 to 1997, four campaigns with stations in all the nine islands of the Azores archipelago, have been realized with a periodicity of about three years. This network has stations on three main tectonic plates: Eurasian, American and African.
The paper presents results of the estimation of displacements parameters, derived from GPS observations only. The values obtained are compared with those derived from analysis of geological and geophysical data. The dynamics of the region is very complex and has not a unique pattern. The results show that, for some of the stations, the displacements are generically consistent, in direction and magnitude, with global tectonics models whereas for other stations more measurements are necessary to allow a better comprehension of the detected movements.

EARTHQUAKE DISTRIBUTION AND MECHANISMS, LITHOSPHERIC STRUCTURE AND TECTONIC REGIMES: TAIWAN

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First, the distribution of earthquakes in and around Taiwan is studied based on 3-D analysis of numerous horizontal and vertical thick sections.
To the west, the lithospheric slab of the Ryukyu subduction zone is twisted and torn, and interrupted beneath northern Taiwan. A fragment plunges towards the NW near the northern tip of the Coastal Range, in relation with oblique collision.
To the south, a lithospheric slab related to the subduction beneath the Luzon arc trends N-S, and dips to the east off southeastern Taiwan. In addition, beneath onshore southern Taiwan, shallow earthquake depths increase toward the SE, in agreement with the subduction at the northern tip of the Manila trench system.
The seismicity of the Longitudinal Valley zone ranges in depth between 0-60 km, with an average seismic surface striking N15°E and steeply dipping to the east beneath the Coastal Range and offshore eastern Taiwan. This major, east-dipping active crustal thrust zone crops out along the active Longitudinal Valley Fault.
Second, inverse methods to reconstruct stress allowed identification of four main stress regimes. To the northeast, N-S extension affects the Ryukyu back-arc basin, southward thrusting prevails at the front of the Ryukyu subduction zone, and a variety of mechanisms reveal complex deformation at the northeast tip of the Philippine Sea Plate. To the southwest, NW-SE compression prevails in the Taiwan collision zone. Normal mechanisms are also present within the Taiwan belt.
Numerical modelling experiments taking into account these seismological properties have the potential to constrain the complex tectonic behaviour of the Taiwan collision zone within a mechanically consistent frame.

EVALUATION OF PRESENT SEISMIC DEFORMATION IN THE WESTERN ALPS

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Relationship between geodetic data and active deformation deduced from seismicity data are studied for the Western Alps, assuming that it is possible to estimate the strain tensor components from the moment tensor components if we split the studied region into zones of relatively homogeneous deformation. The main difficulty of such an analysis in a moderate seismic area is the diffusive character of the seismic swarms. We present here a new methodology to define seismogenic zones based on a statistical analysis of the 3D distribution of earthquakes using a 3D wavelet transform. Then we estimate the present seismic deformation of some of the seismogenic volumes, where the determination of focal mechanisms allows us to conclude that the style of deformation is homogeneous. In most areas the recent seismic deformation is only 1of the movements deduced from geodetic measurements but this estimate mainly enhances the heterogeneity of the mechanichal behaviour of the Western Alps.

SURFACE PROCESSES, SUBSURFACE HETEROGENEITIES AND THE LITHOSPHERIC STRENGH IN THE COMPRESSIONAL AREAS.

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Models of tectonic deformation commonly neglect the surface processes and subsurface heterogeneities such as lateral variations in the crustal composition, minor or healed faults, assuming that they are negligible with respect to the effects of the topography and tectonic forces. Recent problems with estimation of lithospheric strength in cratons and common problems with simultaneous reproduction of realistic vertical tectonic velocities and surface geometries in the mechanical tectonic models suggest that the above factors may play a leading role in many cases. Using a forward numerical approach based on the FLAC algorithm which allows to account for realistic brittle-elasto-ductile rheologies, erosion and ***non-predefined faults***, we show that, for example, in the Kapuskasing Uplift Zone (Canadian Shield), characterized by the absence of surface topography (wiped by erosion), a large granulite intrusion associated with the old thrust fault can be responsible for the observed important (8 km) large scale deflection of Moho comparable with that produced by a 2 *km-high mountain belt.* Our other experiment (applied to Central Asia) shows the crucial importance of the account for the surface processes and distributed faulting in modelling of compressional instabilities (e.g. folding of the lithosphere) and orogeny. Erosion allows to obtain 10 times higher vertical tectonic rates than for the conventional models, and significantly influence the evolution and distribution (spacing) of faults, finite amplitudes of tectonic movements and even the subsurface structure of the lithosphere. In a difference with the traditional opinion, our model show that volumetric shortening, folding and faulting can actually co-exist for a very long time, partly thanking to the stabilizing feedback with the surface processes.

MODELING OF THE SEISMIC CYCLE IN SUBDUCTION ZONES, APPLICATION TO NORTHERN CHILE

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In subduction earthquakes, coseismic elevation changes are opposite to the observed topography. We investigate how this relationship can be understood by studying a 2-dimensional mechanical model that takes into account the mechanical discontinuity of the subduction interface as well as a realistic geometry and rheology. At the time scale of seismic cycle (~100 years), we calculate the displacements associated to a complete cycle, taking into account inter-, co- and post-seismic deformations. At the long time scale (~100.000 ans), we simulate the deformation due to initial geometry (topography, slab radius of curvature and lithosphere thickness), rheology (elastic crust and viscoelastic upper mantle) and boundary conditions (static ones and kinematic ones).
These two approaches at different time scale give consistent results allowing to explain the main features of long term deformations. The main part of the resulting displacement is due to the flexure of the continental lithosphere and to the viscoelastic relaxation of the upper mantle. The distance between the trench and the coast cannot be explained by taking into account only the viscoelasticity of the continental lithosphere. Both approaches indicate that part of the strain must be plastic to explain the topography of the forearc region in northern Chile.

EVOLUTION OF PLATE BOUNDARY IN THE TAIWAN ARC-CONTINENT COLLISION TERRANE

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As at an active orogenic belt in the Western Pacific, the island of Taiwan is unique for comprehensive cause-and-effect studies on convergent margins. Since the Early Miocene, the oceanic lithosphere of the South China Sea began to subduct eastward beneath the Philippine Sea plate, along a proto-Manila trench, thus forming a subduction wedge in front of the Luzon Arc. Continued subduction resulted in an oblique collision of the underthrusting Eurasian continental crust with the Luzon arc at about 6.5 Ma. Because the arc-continent collision stopped the subduction, the proto-Manila trench was transformed southwestward from a plate suture to several thrusts. Starting about 3.8 Ma, the Luzon arc and forearc basin were westward accreted onto the Eurasian continent to generate the Coastal Range in eastern Taiwan. A new plate boundary between Eurasian Plate (eastern Central Range) and the Philippine Sea Plate (Coastal Range) thus formed along the Longitudinal Valley. This new boundary originated as a submarine arc-prism boundary. The shortening caused by the arc-continent collision is accompanied by the formation of east-dipping thrust fault, and the arc-prism boundary is an innate weak zone of the overriding plate. This inference is supported by the observations on the Lichi mélange in the Coastal Range and on the Huatung Ridge off southeastern Taiwan. The Lichi mélange and the Huatung Ridge most likely arose from the shearing of forearc sequences during arc-continent collision, instead of from a subduction complex. Since the last collision began, about 3 Ma ago, the displacement of the Luzon Arc toward Eurasia averaged 150 km in the N310° azimuth, a present-day relative velocity of about 3 cm/yr being detected across the Longitudinal Valley.

CRETACEOUS AND TERTIARY CLOCKWISE ROTATIONS IN THE PUNA PLATEAU (ARGENTINA): TECTONIC IMPLICATIONS FOR CENTRAL ANDES.

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Between 10°S and 30°S, the Central Andes are marked by a major topographic anomaly, the Altiplano-Puna plateau, and by a bended geometry, the Arica elbow. The origin of the curvature of the chain is still controversial. Numerous paleomagnetic results have shown that the northern and southern limb of the elbow were characterised by counterclockwise and clockwise rotations respectively. Two end-members hypotheses are classically proposed, (1) tectonic rotations and curvature of the margin are both the result of a Neogene oroclinal bending linked with the Quechua (Miocene) phase of the andean orogeny and (2) the curvature is of primary origin and rotations result from small-scale crustal block rotations due to the oblique convergence between the two plates. New paleomagnetic results obtained in the Puna plateau combined with a compilation of available data show that the Central Andes are subject to oroclinal bending since at least the Upper Cretaceous. In addition, we suggest that the margin was initially rather straight, striking between N10°-20°W. This interpretation has been compared with results of analogue modelling at lithospheric scale. At regional-scale, amounts of rotations in the back-arc region are also controlled by local features, especially by differential offsets along major thrusts. AMS analysis, kinematic analysis of fault-slip data and structural study of the Puna further constrain the mechanisms which locally control amount of rotations.

RELATIVE MOTION BETWEEN THE CARIBBEAN AND NORTH AMERICAN PLATES AND RELATED PLATE BOUNDARY ZONE DEFORMATION BASED ON A DECADE OF GPS OBSERVATIONS

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GPS measurements in 1986, 1994, and 1995 in the northeastern Caribbean define the velocity of the Caribbean plate relative to North America. The data show eastward motion of the Caribbean plate at a rate of 24 mm/yr (for a site in southern Dominican Republic), a factor of two higher than the Nuvel1-A plate motion model prediction. Independent GPS measurements on San Andres island and at a continuously recording site in Puerto Rico corroborate this result. The GPS results combined with simple elastic strain accumulation models define the strain distribution within this part of the Caribbean/North America plate boundary zone. They suggest that only 30-60% of the total plate motion is accomodated by the Septentrional fault zone (9 ± 3 mm/yr), usually assumed to represent the plate boundary trace. In southern Hispaniola, the Enriquillo fault and the Muertos trough accomodate less than 6 mm/yr of motion. Significant strike-slip and/or oblique dip-slip motion (≥ 5 mm/yr) is probably accomodated offshore, north of Hispaniola, in relation with the oblique collision between Hispaniola and the Bahamas platform.

THE STRUCTURE OF THE CRUST AND THE UPPER MANTLE BENEATH THE LAPTEV SEA IN NORTH-EASTERN SIBERIA

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In north-eastern Siberia, in the Laptev Sea region, the boundary between the North-American and the Eurasian plates changes from sea floor spreading to extension of continental lithosphere. Coming from the north the earthquake epicentres which follow the arctic mid-oceanic ridge spread in the Laptev Sea over an area of about 1000 km^2. The combined use of teleseismic data (focal mechanisms, calculation of the rotation pole of the two plates, attenuation of shear waves) and seismic data (velocity and depth estimations of the crustal units from wide angle reflection / refraction data) allows the following conclusions:

- The crust in the rift related basins is thinned but there are indications for the absence of a mantle plume beneath.
- The epicentres can be correlated with the main structures estimated from seismic reflection data. Presently extension concentrates in the eastern Laptev Sea region while the remaining area seems to build a seperated structure.

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A MODEL OF MEDITERRANEAN LITHOSPHERIC DEFORMATION WITH FINITE ELEMENTS

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Recent geodetical and geophysical results offer new insights into the deformation and depth structure of the Mediterranean area. It has thus become possible to develop more detailed geodynamical models of the Mediterranean area. By using all available information and working with the finite element method (FEM) a three-dimensional image of the dynamics and their kinematic results in the Mediterranean was created. A deformation model was calculated with the help of numerical integration by using observed surface movements and tectonic forces, taking into consideration the material characteristics and the structure of the Earth's crust and upper mantle. MARC was the FE-software in use, which enables to use subroutines in order to solve specific problematic adaptations of the program. The results then received are compared with the stress map of the in-situ measurements. The primarily created test model with purely geophysical parameters was used as a geodetic prediction model for recent crustmovements and delivered locally vastly deviating results. Taking into consideration the results of the geodetical space methods (VLBI, SLR and GPS) as additional boundary conditions, one gets very detailed results of the deformation.

STUDYING PLATE DEFORMATION USING GIS & GPS TECHNOLOGIES

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We present a new method to study current plate tectonic motion using two relatively recent technologies: Geographical Information Systems (GIS) and Global Positioning Systems (GPS). The main aim of this project is to classify the tectonic plates and reveal any inter-plate deformation on the global scale. A GIS system is under establishment to host information on a-priori plate tectonic boundaries, IGS stations, and earthquake seismology data. This system has a bootstrapping procedure to identify clusters of GPS stations that appear to have similar velocities and Euler pole solution. Clusters are identified recursively by selecting IGS stations in the outer regions of the presumed rigid plates and comparing them with those stations in the inner zones of the same plate. Plate rigidity hypothesis is tested by comparing the inner and outer results: if they are in agreement then the plate is considered to be rigid. If the data are not in harmony other geophysical data such as earthquake seismology and fractures are utilised to assist in identifying any previously undetermined boundaries or plate deformation. Input data for 149 GPS stations come from the IGS solutions determined using the fully weighted least squares procedures applied initially for an 18 months span of weekly analysis by the IGS Global Network Analysis Center at Newcastle. International Seismological Centre (ISC) solutions are used for earthquake seismology data. Plate tectonic boundaries and fracture zones were collected through digitizing various data sources. This system of studying plate deformation is still at the early stages of development and there will be future improvements: the ability to use the most recent IGS solution to provide data for longer time spans; the establishment of a new IGS Analysis Center to provide station coordinates for the late-submitting stations; the addition of system flexibility to change the plate boundaries and redefine the tectonic plates; and development of web interface.

CENOZOIC STRESS FIELDS AND DEFORMATION MECHANISM OF FOLD-MOUNTAIN STRUCTURES OF CRIMEA AND SOUTH-WEST CAUCASUS

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The area of research is located in the southern boundary of the ancient East-European plate and the structural elements of the Mediterranean fold belt: the Seythe plate and fold-mountain structures of the Crimea and North-West Caucasus.On the base of the structure-kinematics method of geological data analysis (O.Goustchenko method) about fault slip data sets the space change of stress fields for another time period were reconstructed. These fields create the space-time rows reflecting the consistent change of a loading conditions of the southern boundary of the plate and the fold belt. The deformation mechanism for the Cenozoic period is proposed on the base of comparison of the space-time rows with the peculiarities of geological development of the area. The reconstructed stress fields and assumpted deformation mechanism are connected to the collision of the Arabian plate and southern boundary of the East-European plate. The change of tectonic stress type and principal stress axes inside the kinematics zones of reconstruction during of the Cenozoic time are connected to the direction of displacement of the compression situation as a consequence of movement of the Arabian plate toward the ancient plate.

SUBDUCTION-RELATED DEFORMATION AND LONG-TERM COMPRESSION IN THE CENTRAL AND SOUTHERN ANDES DERIVED FROM GPS

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Crustal Deformation in the Central and Southern Andes is controlled by both, different types of reversible deformation near the subduction plate boundary and long-term compression in the Sub-Andean range in more than 600 km distance to the Peru-Chile trench. In order to detect the different types of deformation, the GFZ Potsdam established the large GPS network SAGA (South American Geodetic Activities), covering Chile and parts of Argentina, in cooperation with various organizations in the host countries. A dense part of the network in Northern Chile and Northwest Argentina (72 sites) was re-observed 3 months after the Ms=7.3 Antofagasta subduction earthquake which ruptured the area on July 30, 1995. The large number of sites allows to invert the coseismic slip distribution from observed surface displacements. The residual displacements, corrected for interseismic coupling and coseismic deformation, reflect deformation due to crustal shortening in the Sub-Andes. In 1996, 120 sites between Arica and Pto. Montt (18°S to 42°S) were re-observed. Results indicate a high interseismic coupling that is remarkably homogeneous along-strike. Postseismic displacements in the rupture area of the very large 1960 Chilean earthquake and the Antofagasta earthquake are significantly different from those derived in parts of the net that are dominated by inter-seismic deformation, and most likely influenced by visco-elastic stress relaxation.

PRELIMINARY RESULTS OF GPS MEASUREMENTS ACROSS WESTERN NEPAL.

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The Himalaya undergoes at present, about one-third of the today convergence between India and Eurasia (58 +/- 4 mm/a). The present-day deformation of the Himalaya is characterized by big earthquakes (nearly half of the chain has ruptured over the last century), and by a significant uplift reaching 7 +/- 3 mm/a. The historical sismicity of Nepal indicates the occurrence of big earthquakes in the eastern and central Nepal, the western Nepal being characterized by a lack of recent big earthquake. To study the present-day deformation of the western Nepal a GPS network of 29 benchmarks has been measured in November 1995 (IDYLHIM project) with 9 points of the 1991 CIRES network (Bilham et al., 1997). A comparison of the 1995 and the 1991 data has already been performed (Bilham et al., 1997). This GPS displacement field and the levelling data indicate that the slip of India beneath Himalaya and Tibet can be approximated by a single dislocation with a ramp located in the central Himalaya (Bilham et al.,1997) where an important microsismicity is recorded. A part of the network has been measured again in November 1997; we will present here the first results of the 1995/1997 comparison.

Ref: Bilham et al. (1997), GPS measurements of present-day convergence across the Nepal Himalaya. Nature, Vol 386, 1-94.

PRESENT EVOLUTION OF THE PACIFIC-AUSTRALIA-ANTARCTICA TRIPLE JUNCTION BASED ON SLIP VECTOR DEVIATIONS

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Local pole of PAC-AUS motion have been derived from slip vectors of the earthquakes along the Macqurie ridge by Frohlich et al. (1997). This local pole locates about 3 degrees far from that of NUVEL1 in NNW direction. This insight proposes another closure of velocity triangle near the triple junction. Based on the analysis of slip vector deviations from NUVEL1 predictions, events of eastern most AUS-ANT plate boundary show clear negative deviations (measured clockwise). This deviations are convenient for the closure of velocity triangle stated above. Such deviations of near the triple junction of PAC-ANT boundary are not well determined, but the deviations are almost zero. These results suggest that present reorganization of plate boundaries is in progress at AUS-ANT and PAC-AUS boudaries rather than PAC-ANT. Shape of velocity triangle which determined for near the triple junction is almost strait line, and satisfies stable condition of the triple junction. Lodolo and Coren! (1997) pointed out the important

INTERACTION OF TWO ACTIVE DECOLLEMENTS AND ANTIFORMAL STACKING IN SANDBOX ACCRETIONARY WEDGES

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The dominating mode of deformation and mass transfer observed in scaled sandbox experiments in case of high basal friction is cycling between frontal accretion of short imbricate thrust slices and underthrusting of long, undeformed sheets. A weak layer in the incoming section changes the style of deformation and provides a mechanism for material transfer over long distances beneath a large buttress.
These observations are the basis for experiments with two partly overlapping weak horizons and a relatively steep buttress in order to investigate in more detail active planes of movement and modes of mass transfer.
Each weak horizon entering the deformation front acts as a décollement and changes the style of deformation. Thus, the two weak horizons act as simultaneously active décollements, which leads to a complex pattern for imbricate thrust slice formation with one or two thin shallow slices in between a sequence of deep reaching thrust slices which go down to the lower detachment level and therefore comprise larger spacing.
The observed modes of material transfer and style of accretionary growth compare well to the convergent margin off Japan, where a shallow décollement has been observed, and the Chilean margin, where underplating in deep stages takes place.

VELOCITY FIELD FOR THE EASTERN MEDITERRANEAN

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We combine GPS data for the period 1988 - 1996 in order to determine an internally consistent estimate of contemporary deformation for much of the eastern Mediterranean region. The northward motion of Arabia is detected at stations in SE Turkey and is slightly less than the NUVEL-1A Arabian plate rate, although the difference is within the uncertainties of both estimates. Northward motion of Africa is more ambiguous in the present GPS data - two GPS stations near Cairo show slower than expected motion. Further observations are needed to substantiate any significant deviation from NUVEL-1A. The data define the coherent rotation of Anatolia and constrain internal deformation to below 2 mm/yr. The southern Aegean region is also characterized by small internal deformation and is separated from the Anatolian region by a zone of N-S extension in western Turkey. A significant deviation from coherent motion occurs in the southeastern Aegean which shows anomalous motions towards the Hellenic trench. We will present a detailed interpretation of the velocity field and consider the implications for ongoing dynamic processes.

BLOCK MOSAIC AND SEISMIC MANIFESTATIONS IN BULGARIA

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The block mosaic is constructed on the basis of satellite images. The block configuration could be interpreted as a result of the previous Alpine evolution and of the post-Alpine movements and deformations. The horizontal and vertical movements, also the deformations were realised in the conditions of the S boundary of the Europe-Asian plate, that was going in a contact with the African plate.

The seismic events (mainly the earthquakes of M<=7.8 and some brontide manifestations) taken place on limited sectors of the high-sized block boundaries and sometimes - in their inner parts. In the XX c. the 3 of the 4 earthquakes of M>=7 have the epicentres near the S and SE margins of the Moesian microplate.

The recent movements of the Moesian microplate and of the closely related to it the Black Sea, the Aegean and the Adriatic ones, also their position in the Euro-Asian plate contact zone create the seismic potential of the Balkan region, including of Bulgaria.

INTEGRAL DEFORMATION OF THE CENTRAL INDIAN BASIN FROM EOCENE PLATE RECONSTRUCTIONS

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The Central Indian Basin is the locus of active and intense deformation resulting from relative motions between the Indian and Capricorn plates (the Capricorn plate is the portion west of ~80°E of the formerly called Australian plate). Seismic stratigraphy and deep sea drilling suggest that this deformation started 7.5-8.0 Myr ago. However, high-resolution plate reconstructions for the past 20 Myr along the Carlsberg and Central Indian ridges, which record the motions between the Indian and Somalian plates (north of 4°S) and between the Capricorn and Somalian plates (south of about 10°S), have shown that the resulting India/Capricorn reconstruction for chron 6 (20 Ma) differs significantly from every younger reconstruction, including that at 18 Ma (chron 5E). This result implies that the motion between the Indian and Capricorn plates began before 18 Ma.

Here we investigate further this question by comparing high-resolution reconstructions of the Carlsberg and Central Indian ridges at Eocene times (chrons 20 - 24; 43 - 53 Ma), prior to the collision between the Indian and Eurasian plates. Differences at each chron between the two sets of finite rotations yield the integral motion between the Indian and Capricorn plates. and hence the integral deformation in the Central Indian Basin.

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AEGEAN-AFRICAN BOUNDARY TECTONICS FROM CRETE: *CRETE REGIONAL TECTONIC EXPERIMENT.*

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The establishment of a regional array in this very active subduction zone was prompted by the intense seismicity in this area. Crete, located in the forearc of the Hellenic subduction zone is a natural laboratory for deformation monitoring. The array comprises a base station at Chania (in operation for several months now), a second permanent site collocated with the tide-gauge at the Naval Base of Souda, near Chania, and the incorporation in the future of 3-4 sites previously used in GPS and SLR campaigns on Crete. This is the first time that a permanent site of any space technique is located on the island. As the array is slowly deployed to cover the west and central parts of the island over the next two years, we will use the accumulated GPS data along with data from European and African sites to determine precise relative motion vectors and regional deformation fields. We expect that concurrent efforts to expand the regional GPS networks in northern Africa and over the Arabian plate will help create a more complete picture of a very complex tectonic region. Our permanent GPS array will also contribute in the densification of the IGS network in this region, in tide-gauge and seismic hazard monitoring, and in numerous local applications. There is a plethora of numerical models for this area; we expect that by complementing other permanent networks in the Eastern Mediterranean-Aegean area we will soon have the data to discriminate between them.

A FLUID INDENTOR MODEL FOR THE DEFORMATION OF CONTINENTAL MARGINS: A MODEL FOR SOUTH AMERICA

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The general circulation of the convecting mantle in the earth is responsible for driving surface plates and moving continents. The small scale patterns of this circulation are what determines where and when forces are applied locally to surface features. For example, a horizontal stagnation point flow impinging on the deep cratonic root of a continent will set up a stress distribution along the continental margin that exhibits a maximum in normal stress at the stagnation point. This stress distribution will act as a fluid indentor, deforming the continent over time. We postulate that this type of flow pattern exists in the mantle off the west coast of South America and has contributed to the deformation of the South American coastline and the rise of the Andean orogen. Shear wave splitting data which indicates trench parallel flow in the mantle beneath the subducting NAZCA plate off the west coast of South America and the high degree of symmetry in geoid and topography to the north and south of the Altiplano are consistent with a local horizontal stagnation point flow pattern in the mantle. We will use results from a finite element model of mantle circulation with a non-Newtonian and temperature dependent rheology similar to that expected in the earth's mantle to understand in more detail the consequences of a horizontal stagnation point flow.

GRAVITY, SEISMICITY AND TECTONIC SIGNATURE OF ARC-CONTINENT COLLISION : RESULTS FROM PHYSICAL AND NUMERICAL MODELLING.

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The process of arc-continent collision is modelled both experimentally and numerically. The experimental approach allowed us to simulate the whole process including interaction of the plates between them and the plates with the asthenosphere. However, the precision of this approach is relatively low. Therefore we use the finite-element numerical modelling to precisely calculate the stress-strain state of the overriding plate carrying the volcanic arc. We modelled the deformation only of this plate, applying the boundary condition (the interplate pressure) derived from the physical modelling. The results are the followings: subduction of the continental margin increases the compression of the overriding plate which finally fails along one of two possible directions dipping under the arc from either of its sides. Both deformation and the mode of failure depend on the distance between the arc and the trench, the interplate friction and the thickness (geometry) of the subducting crust. The modelling results are compared with relief, seismicity, gravity, and GPS data from the two regions of ongoing arc-continent collision in Taiwan and Timor. Based on the comparative analysis we define the style of lithospheric deformation in both regions.

DEFORMATION IN THE PALU-KORO FAULT REGION (SULAWESI) OBSERVED BY GPS

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The Palu-Koro fault in Central Sulawesi is a major strike-slip fault which transforms the high relative plate motions of the Australian, Philippine and Eurasian plates in their triple junction region, but which has shown no large earthquakes in the last one hundred years. The kinematic behaviour of the Palu fault has been investigated by GPS observations on a 50 km transect across the fault since 1992. The observations show that the fault is locked, but the locking depth could be evaluated only with high uncertainties. It was observed that the strike-slip rate changed around 1995 from 2.6 cm/yr to more than 6 cm/yr, probably due to co-seismic motion caused by two earthquakes in the Minahasa trench. New measurements which have been carried out in 1997 will help to verify this hypothesis. Furthermore, this paper attempts to improve the determination of the deformation field across the Palu fault by combining results of previous analyses and the information gained from the new measurements.

1995-1997 SURFACE DEFORMATION ALONG THE HUSAVIK-FLATEY TRANSFORM FAULT AND AROUND ITS JUNCTION WITH THE NORTHERN VOLCANIC ZONE IN ICELAND.

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The Tjörnes Fracture Zone (TFZ) is a rigth lateral transform zone which connects in the Northern Iceland the rift zone to the Mid-atlantic oceanic ridge. The most important feature of the TFZ is the Husavik-Flatey fault whose eastward continuation outcrops south of the Tjörnes peninsula. This transform fault is connected to the most westward fissure swarm of the rift zone. At this place the Husavik-Flatey Fault is cut by normal faults of the Theistareykir fissure swarm and apparently does not extend to the east. Historical seismicity has been observed along the Husavik-Flatey fault and it is now proposed that the main part of the plate motion is accommodated along this discontinuity.

The present-day displacements can be measured along the strike of the fault at variable distances in the range of 0-50 km. A dense GPS network has been installed there and we measured 32 benchmarks both in 1995 and 1997. Both 1995 and 1997 shows a mean repeatability of about 2 mm for the horizontal components. These results are accurate enough to compare the detailed displacement field with the fault pattern and the location of seismicity occurring during the same period.

INTERPRETATION OF GPS OBSERVATIONS IN THE TRIPLE JUNCTION AREA IN INDONESIA

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The triple junction of the Eurasian, the Philippine, and the Australian plate in Indonesia has now been observed by GPS over a three years' time span. The results of the first repeat measurements in 1996 have already shown the tectonic complexity of the region. A kinematic model had been established, indicating a rigid clockwise rotation of the Sula block in North Sulawesi, coherent with geological observations. It suggests that the Sula block is related with the Australian plate to the South by a zone of continuous deformation. In 1997, important repeat measurements have been conducted. The tectonic model can now be constrained by new velocity vectors on the Sula block and a first estimate of the steady state velocity of Tomini (North Sulawesi), a station affected by earthquakes in earlier observations. For stations with three measurement epochs there is now evidence for either a steady state velocity or a non-linear displacement. This allows us to identify the limits of the rigid Sula block, the deformation zones along the block boundaries and the continuous deformation zone in the Southern triple junction area.

Recent seismic activity at the edge of rift propagation in the Gulf of Elat (Aqaba)

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The Gulf of Elat (Aqaba) is the seismically most active segment of the Dead Sea Fault (DSF), which separates the Israel-Sinai sub-plate from the Arabian plate. In November 1995, the Mw=7.1, Gulf of Elat earthquake displaced left-laterally a 50 km long fault segment by 3 meters. This earthquake was preceded by three swarm events (occurring in 1983, 1990, and 1993) and was followed by thousand of aftershocks. The center for this seismic activity is the central Gulf, a region characterized by deep bathymetry (1800 m b.s.l - the deepest in the Gulf), open cracks, folds, and faults. Structurally, it is a symmetric pull-apart basin located above a transitional zone in the crust, where the Moho depth decreases from 35 km in the northern Gulf to 28 km in the south. Ben-Avraham [1985] suggested that the central Gulf represents the edge of rift propagation. The coincidence of the short-term seismic and longer-term tectonic activity in the central Gulf suggests that this region is significantly more active than other segments along the DSF. The excess seismicity in the central Gulf reflects the combined effect of horizontal motion along the plate boundary and the upper crustal response to deep rift propagation processes. Thus, we suggest that the repeat time for large earthquake along the central Gulf is significantly higher than along the other fault segments along the DSF.

03 Seismological studies in convergent plate margins

Convener: Kissling, E.
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SEISMOTECTONICS OF CENTRAL AMERICA: A STUDY OF EARTHQUAKE FOCAL MECHANISMS

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We have analyzed an extensive earthquake mechanism data base compiled for the entire Central American region between 4-19°N and 77-93°W. Rose diagrams, showing the horizontally projected pressure axis, and triangle representations were used to classify and categorized the stress regime and the preferred tectonic environment. Results indicate that in general, our findings are consistent with current plate models. The main tectonic feature corresponds to the subduction of the Cocos plate beneath the Caribbean plate and Panama Block. Polochic-Motagua-Swan and Panama Fracture zone systems are well resolved and correspond to Caribbean-Northamerica and Cocos-Nazca plate boundaries respectively. Intraplate Caribbean and Panama Block seismicity corresponds mainly to internal deformation along the collision zone, and occurring in shallow strike slip faults, mostly associated with the volcanic chain. Only two major anomalies were found, one within the subducted Cocos slab beneath El Salvador and the other a shear zone traversing Central Costa Rica connecting the Middle America Trench and the North Panama Deformed Belt.

STRESS FIELD DISTRIBUTION IN THE TYRHENIAN REGION AS DEDUCED BY INVERSION OF EARTHQUAKE FOCAL MECHANISMS

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The study is based on the detailed geometry of the Tyrhenean Wadati-Benioff zone (**TWBZ**) and the deep seismically active fracture sones (**FZ**) in the continental wedge as delineated by Hanus & Vanek. Earthquake focal mechanism solutions and the inverse technique of Gephart and Forsyth (1984) were incorporated for determining the best fit principle stress directions σ_1, σ_2, σ_3 and the ratio $R = \sigma_2 - \sigma_1/\sigma_3 - \sigma_1$ for the **TWBZ** and seven **FZ**. The best fit stress model for the **TWBZ** shows that the maximum compressive stress is paralel to the slab. The minimum compressive stress trends SE and is almost normal to the slab. No clear tendency in orientation of the σ_1 and the σ_3 in the considered **FZ** is found.

THE NANKAI TROUGH SEISMOGENIC ZONE EXPERIMENT: RESULTS OF WIDE-ANGLE OBS DATA

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The Nankai trough, southwestern Japan, is recognized as a vigorous seismogenic zone with well studied subduction earthquakes. The R/V KAIREI (JAMSTEC) was used to acquire wide-angel seismic data around the Nankai trough across a co-seismic slip zone of the 1946 Nankaido earthquake (Ms=8). A total of 25 ocean bottom seismographs (OBS) and one land station were deployed along three dip (50 - 250 km) and strike (120 km) profiles. A main purpose of the wide-angle seismic experiment is to investigate a detailed structure of the rupture zone of the last great earthquake. Simultaneous multichannel seismic (MCS) reflection data were also acquired (see poster by Park et al.). A model along the main dip profile, obtained by combined forward and inversion modeling of the OBS data, shows thick accretionary sediment (8km thick) and subducting oceanic crust down to 25 km depth. We found that the boundary between the accretionary sediment and the crystalline forearc crust is located at 20-50 km landward of the oceanward edge of the co-seismic slip zone. The MCS data also shows a clear thrust fault cutting through the accretionary sediments. These results strongly suggest that the rupture zone of the 1946 earthquake farther extends into the accretionary sediment beyond the forarc-oceanic crust boundary.

SEISMICITY AND STRESS TENSOR INVERSION IN THE CENTRAL WASHINGTON CASCADE MOUNTAINS (USA)

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The tectonic setting of north-western United States is dominated by the interaction between three plates. The small oceanic Juan de Fuca plate subducts beneath the North American one which, on a larger scale, is moving to the south-east relative to the Pacific plate. While the Cascade Range volcanoes result from the subduction process, crustal tectonics are dominated by N-S compression due to the North American-Pacific plates interaction. In this study we use ca. 550 selected earthquakes in the central Washington cascade mountains to study in detail the uniformity of the stress tensor in this volcanic arc region. Earthquakes from the PNSN catalogue were divided into several subsets based on epicentral and depth groupings and stress-tensor inversions using the Gephart and Forsyth technique were computed for each group. As in previous similar studies the maximum compressive stress axis (sigma-1) is nearly horizontal and trending ca. N-S and NNE-SSW. However, the minimum compressive stress axis (sigma-3) deviates from vertical to horizontal for different groups of events. In particular, events in the depth range of 10-14 km in the Western Rainier Seismic Zone (WRSZ) have near vertical sigma-3 direction while other depth ranges in this area show a near horizontal, E-W sigma-3 orientation. We hypothesize that the change in orientation of sigma-3 for the 10-14 km depth range in the WRSZ is probably due to the influence of the nearby Mount Rainier magmatic system.

ANCORP'96 - SUBDUCTION ZONE IN THE CENTRAL ANDES IMAGED BY SEISMIC REFLECTION SURVEY

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A very deep reaching 400 km long, combined seismic reflection and refraction profile was performed from Sept to Dec 1996 in the Central Andes at 21 degree S. Its aim was to image and model the structure and deformation processes of the collision of the South American continent with the subducting oceanic Nazca plate. Borehole shots with 90 kg explosives each were used as seismic sources at a spacing of 6.3 km. The moving 252-channel spread with geophone group spacing of 100 m resulted in a nominal 4-fold CMP coverage. Wide-angle measurements were integrated by repeating shots with increasing energy at an average spacing of 30-50 km. In the same area, an array of stations was installed from Nov 96 to March 97 for monitoring local earthquakes. The most remarkable feature of the near-vertical recordings is a band of reflections, 5-8 km wide, seen at about 10-13 s TWT beneath the coast dipping towards the east to 28 s TWT (approx. 80 km depth) at about 130 km from the coast. The Wadati-Benioff zone does not coincide with these prominent reflections, but is vertically offset into the oceanic mantle by 15-20 km. At about 8 s TWT, above the sudden end of the dipping band of reflections, a very pronounced bright spot is seen, located at the western rim of the recent volcanic arc. We suggest that the reflections are caused by a fluid- or magma-enriched zones fed by dehydration processes in the subducting oceanic plate.

STRUCTURE OF THE CRUST IN CENTRAL ANDES INFERRED FROM POISSON'S RATIO

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We use Poisson's ratio derived from the inversion of P and S travel times of local earthquakes to infer the structure of the crust in the Central Andes. Poisson's ratio is deduced from P- and S-velocity models obtained using the Thurber's 3D iterative simultaneous inversion method. The seismic network crossed the main structures of the Andean chain in northern Chile and southern Bolivia (20S), from the Coastal Cordillera to the Subandean Zone. At shallow depth, variations of Poisson's ratio and P-wave velocity are closely related and a good agreement between Poisson's ratio and geological structures is observed. In the lower crust, large variations of Poisson's ratio are observed while P-wave velocity is more homogeneous. Our model confirms that crustal shortening and magmatic addition are involved in the thickening of the Andean crust. Poisson's ratio model supports the idea of large areas of partially molten rocks in the lower crust beneath the Western Cordillera. Inversely, beneath the Central Altiplano Basin, the model indicates a felsic composition and is consistent with thickening by compressive shortening. Therefore thickening of the Andean crust can be roughly estimated to be due to magmatic addition between 69W and 68W and crustal shortening east of 68W.

ANCORP'96: AN IMAGE OF FLUID ESCAPE FROM SUBDUCTION ZONE IN ANDES ?

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Two strong reflective zones are imaged at a depths of 20-30 km and 40-80 km in the Central Andean forearc at 21°S as a result of ANCORP'96 experiment. Deep reflective zone (Nazca reflector) is dipping sub-parallel to the Wadati-Benioff zone, but is by 20 km above it . Intensity of the Nazca reflector increases downdip with the brightest reflections at the 65-75 km depth range but abruptly decreases deeper than 80 km. Both brightest part of the Nazca reflector and shallow reflection zone (QB bright spot) are exceptionally bright reflectors with estimated apparent reflectivity coefficients higher than 0.2.
Three interpretations of the Nazca reflector are discussed in which it is associated either with the active metamorphic-reaction front in the mantle of upper plate or with friction melting within intraplate shear zone or with subducted eroded continental material. Those different models could be efficiently distinguished from joint interpretation of P- and S- wave reflections which is however limited because only vertical-component seismic records are available.
The preferred model explains both Nazca reflector and QB bright spot as fluid traps located at a fronts of recent hydration of the mantle (Nazca reflector) and crust (QB bright spot) the fluids being supplied by the dehydration of the subducting Nazca plate. If this model is correct than intermediate earthquakes within the plate can not be directly associated with the dehydration of the subducting plate.

1D VELOCITY MODEL ESTIMATION IN COSTA RICA, CENTRAL AMERICA

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Earthquake activity occurring in Costa Rica, and its vicinity, confined to an area 7 -12° N and 82 - 88°W, with a depth range of 0-to-250 km, and recorded by the Universidad Nacional de Costa Rica seismographic network (OVSICORI) during the period 1984-to-1997, has been accurately relocated and simultaneously inverted for the minimum 1D velocity model. We used hypocenter distributions and focal mechanisms to investigate the stress field generated by earthquakes within this region. Epicenters of the relocated earthquakes are distributed: along the subduction zone, the Panama Fracture Zone, a transcurrent plate boundary that traverses central Costa Rica from west to east, the North Panama Deformed Belt and the Hess Escarpment. In general relocated events have small location errors and a RMS of 0.2 sec, approximately. Recorded events were relocated at different depths, with relatively homogenous distribution in the upper 20 km. Below this depth, relocated earthquakes are mainly concentrated along the main thrust zone and within the subducted Cocos plate.

NONLINEAR INVERSION OF TELESEISMIC P WAVE TRAVEL TIME RESIDUALS IN NORTH WESTERN ITALY

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About 8000 teleseismic P wave arrival times have been picked from 490 earthquakes recorded by regional and temporary seismic networks installed in North Western Italy and surrounding regions.
The travel time residuals have been computed considering as starting velocity structure the IASPEI 91 radial Earth velocity model and then inverted using a non linear inversion procedure.
Synthetic tests have been carried out to determine the influence of a three dimensional ray tracer on the tomographic images, when structures with large velocity gradients exist.
The three-dimensional model confirms the presence of strong lateral heterogeneities in the litho-asthenospheric system. In the shallower layers high and low velocity anomalies follow the structural behaviour of the Alpine-Apenninic chains. In the deeper layers the tomograms reveal with unprecedented accuracy the location and shape of the already known high velocity anomaly beneath the North Western Po Plain. Moreover, looking at the seismicity of the investigated region, the deepest events were found to be confined in the anomalously high P wave velocity zone.

DELIMITATION OF DOMAINS WITH UNIFORM STATE OF STRESS IN THE WADATI-BENIOFF ZONE BENEATH JAVA

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Tectonic stress analysis in the Wadati-Benioff zone beneath Java was performed by means of the method of Gephart and Forsyth (1984) using P- and T- axes parameters from Harvard Centroid Moment Tensor Solutions 1977-1995.
The analysis led to the delimitation of five domains with uniform tectonic stress, which clearly differ in principal stress directions. The domains form belts parallel to the plate boundary from the very beginning of the slab to its maximum depth. The stress changes along the plate boundary were much less pronounced than the changes with depth. The slab is aseismic between individual domains. The tectonic stress zonation was compared with some other subduction zones (e.g. Sumatra).

THE CHARACTERISTICS OF STRESS FIELD IN THE HUALIEN AREA, EASTERN TAIWAN REVEALED FROM EARTHQUAKE RUPTURE PROCESS

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The Hualien area, eastern Taiwan, is around the collision boundary of the Philippine Sea and Eurasian Plates. The abnormal seismic related phenomena often reveal the complexity of the stress field at this particular region. In this paper, we used the inverted earthquake rupture processes and the data obtained from Global Position System (GPS) to discuss the characteristics of local stress field in the Hualien area. The seismograms of local network and of some teleseismic data were used to invert the distribution of stress drops and slips over the fault planes for some earthquakes. Based on the inverted results, the theoretical coseismic displacement fields produced by earthquakes were computed and compared with the GPS measurements. The controlled parameters in inversion are slip, rake, rupture velocity, and rise time at each sub-fault. Genetic Algorithms was used in searching the minimum misfit between the observed and synthetic seismograms. By contouring the parameters for all sub-faults of a certain event, the rupture process and its dynamic property can be inferred. The results show the earthquakes studied possess different rupture patterns. The stress build-up and release at eastern Taiwan is extremely localized. The compound earthquakes within 30 km in distance and 17 hours of lag time in this region did not induced by the same stress system.

SE18 From EGT to EUROPROBE: joint European geoscientific initiatives

Convener: Gee, D.G.
Co-Convener: Blundell, D.J.

Sponsorship: ILP, ESF

COMPARISON OF GEOELECTRIC STRUCTURE FOR BELORUSSIAN CRISTALLINE MASSIVE AND UKRAINIAN SHIELD

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Belorussian Crisalline Massive (BCM) and Ukrainian Shield (USh) are separated by Pripyat Depression of approximately 100 km width. Several hundreds of deep MTS were made in frameworks of EUROPROBE and EUROBRIDGE projects. The level and form of MTS curves are approximately the same both for the north-west part of USh (Vinnitsa zone of Podol's geoblock) and BCM. Cross-section of the region includes moderately conducting crustal conductors of integral conductivity 500-1500 Sm with depth of upper one be equal 10-15 km. The border of USh and BCM geoelectric similarity is traced by Devladov regional deep fault in the south and Talnov deep fault in the east. To south and especially to east from this border crustal conductivity increases up to 2000 - 5000 Sm and is characterized by strong spatial inhomogeniety.

MAGNETIC EVIDENCE FOR THE GEOMETRY OF THE EASTERN MARGIN OF THE EAST EUROPEAN CRATON

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The eastern part of the East European Craton (EEC), adjacent to the Middle and Southern Urals, is characterised by broad, large amplitude magnetic anomalies due to sources within the crystalline basement. These most commonly have E to NE trends, and contrast markedly with the N-trending, shorter wavelength anomalies over the accreted terranes of the Uralide orogenic belt to the east. The trace of a line drawn along the truncation of the characteristic EEC anomalies has been compared with structures mapped at outcrop and with seismic reflection data from four E-W transects. Typically, it is offset to the west of the Main Uralian Fault, crossing Precambrian units which were subject to relatively modest westward-directed thrusting during the Uralian orogeny. In contrast, the magnetic models require either a major down-to-the-east displacement of underlying magnetic basement or juxtaposition of dissimilar basement units. The Zuratkul Fault separates sedimentary units with different pre-Vendian deformation histories and thus could separate underlying rocks with different magnetisations. However, the fault inferred from seismic evidence and the modelled magnetic margin do not coincide precisely. Whatever its relationship with surface structures, it appears likely that the truncation of EEC crystalline basement occurred during pre-Uralian times and was most probably associated with early Riphean rifting and Vendian convergence.

CRUSTAL-SCALE STRUCTURE OF THE FOOTWALL TO THE SUTURE ZONE, SOUTHERN URALS

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The footwall to the suture zone (the Main Uralian fault) in the southern Urals consists of a west-vergent thrust stack that developed in two main stages. Integration of reflection seismic profiling and potential field data with structural field mapping show the crustal-scale architecture to be an imbricate thrust system of the foreland thrust and fold belt, structurally overlain by a stack of allochthons. Depth to detachment calculations made from field data and reflection seismic profiles suggest that the basal thrust of the foreland thrust and fold belt is located within the Precambrian basement of the East European Craton, and it cuts continuously up section towards the west. Potential field data help correlate the structural architecture with pre-existing basement features. Shortening is calculated to be 17 km. Deformation in the imbricate thrust system occurred from Late Carboniferous to Early Triassic times. The allochthons overlying it comprise an accretionary complex whose development and emplacement can be related to the arc-continent collision that occurred between the Magnitogorsk arc and the East European Craton during the Late Devonian to Early Carboniferous. The timing and mechanism of final emplacement of the highest structural unit, the Kraka ophiolite, is not well known. The allochthons were carried in piggy-back fashion during foreland thrust and fold belt development. The reflection seismic profiles image the base and internal structure of the accretionary complex and its contact relationships with the structurally underlying deformed East European Craton. The entire thrust stack is bounded to the east by the Main Uralian fault, which also forms the mechanical boundary between the accretionary complex and the Magnitogorsk arc.

PALAEOMAGNETISM OF PROTEROZOIC ROCKS FROM THE UKRAINIAN SHIELD AND THE CONSOLIDATION OF THE EAST EUROPEAN CRATON

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A palaeomagnetic study has been performed on Palaeo-Mesoproterozoic rocks sampled from three different crustal blocks of the Ukrainian Shield. Characteristic magnetizations were defined in 1.77-1.72 Ga anorthosites, basic dykes and in a 2.0 Ga monzonite. On basis of these results a sequence of 2.0 Ga to 1.72 Ga apparent polar wander was defined for the Ukrainian Shield and Sarmatia. These poles are significantly different from the APWP of Fennoscandia and the calculated orientations and positions of Sarmatia during this time demonstrate that it was not in its present position relative Fenno-scandia. One pole of a basic dyke fall on the APWP of Fennoscandia and may indicate that the time of accretion of Fennoscandia to Sarmatia is between 1.72 Ga and 1.58 Ga. Sarmatia and Fennoscandia may have formed a part of a supercontinent that was assembled in the Mesoproterozoic.

NARS: SEISMIC STUDIES OF THE EUROPEAN MANTLE USING MOBILE BROADBAND STATIONS

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The history of the Network of Autonomously Recording Seismographs (NARS) now spans 15 years. During this time the 14 broadband stations of this network have been employed in different configurations: as a linear array from south Sweden to southern Spain, in Iberia, in The Netherlands and its immediate surroundings, in the former Soviet Union, and in Finland. Seismic results have been obtained in many different studies, among which a 3-D surface wave inversion of the upper mantle shear-velocity structure, measurements of seismic anisotropy using shear-wave splitting and surface wave inversion, and local studies of crustal structure. In this presentation an overview is given of the various types of studies carried out using the NARS data in relation to the structure of the European continent. Emphasis is given on recent results of the seismic structure beneath the East European Platform.

NEW QUANTITATIVE APPROACH TO ESTIMATE THE SEDIMENTARY BASINS' UPLIFT: IMPLEMENTATION TO THE DNIEPR-DONETSK BASIN, UKRAINE

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A numerical technique to estimate the sedimentary basins¶ uplift during inversion tectonic activity is proposed. It is based on backstripping technique, on forward modelling and on new developed approach. The forward modelling is based on two-layer stretching assumptions, for the thermal calculations a numerical finite difference method was used, which allows incorporation of finite and multiple stretching phases. In a new offered technique the eroded thickness is reconstructed in a way by variation its initial minimal value and from lithology of full stratigraphic sections. Uplift value is determined as difference between observed basement subsidence and new calculated basement subsidence for restored thickness.In the Dniepr-Donets Basin, the amount of Permian uplift, calculated for thirty startigraphic sections located in the south-eastern flank, is up to 2000 m. Along with interpretation seismic data, lithology and in combination with forward modelling a reconstruction of basins¶ uplift is possible.

SE19 The Trans European Suture Zone (TESZ)

Convener: Thybo, H.
Co-Conveners: Guterch, A.; Pharaoh, T.C.

THE BALTICA-AVALONIA SUTURE in the SE North Sea

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The concealed Caledonian Baltica-Avalonia Suture in the SE North Sea is a transitional-type crust separating a three-layered, high-velocity Baltica shield-type crust to the north from and a two-layered low-velocity Caledonian-type crust to the south. The crustal velocity models are very similar along the two sub-parallel, N-S trending MONA LISA profiles ML1 and ML2, but there is a major difference in the reflectivity and the velocity structure of the uppermost mantle. Strong S- to W-dipping mantle reflections are imaged by normal-incidence and wide-angle reflections along ML1, ML2 and the E-W trending ML3; but only resolved by refraction phases along ML2 as a high-velocity (8.65 - 8.8 km/s) layer. Weaker N- to E-dipping normal-incidence mantle reflections are observed along ML1 and ML3 which are not seen along ML2 because the profile is located to the south of the NE-dipping structure. This structural difference indicates a change from east to west in the lateral extent of the features which we interpret as Caledonian inherited upper mantle structures. Additionally, the mantle velocity above the NE-dipping reflector is low (7.8 - 8.1 km/s). We interpret this as former Baltica lower crust transformed into eclogite facies by high pressure, low temperature metamorphism as a result of Caledonian lithospheric flexure. The N- to E-dipping mantle event is interpreted as the Tornquist Sea subduction zone, which is overprinted by the younger S- to W-dipping mantle event - a late-Caledonian or Late Carboniferous to Early Permian mantle shear zone. The high velocity mantle is consistent with velocity anisotropy from "frozen-in" alignment of elongated mafic minerals in rocks of peridotitic composition.

EFFECTS OF 3D CRUSTAL STRUCTURE ON TELESEISMIC WAVEFRONTS REGISTERED AT THE TOR ARRAY

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The determination of a reliable 3D image of the lower lithosphere and asthenosphere by inversion of teleseismic traveltime residuals obtained from the TOR seismic array requires a priori correction for 3D crustal effects. Crustal traveltime contributions are determined by tracing teleseismic wavefronts through a parametrized 3D crustal structure. We compiled a simplified 3D velocity model for the crust and uppermost mantle for the region encompassing northern Germany, the Tornquist zone in Denmark, and southern Scandinavia. The network of active seismic profiles in the area was used to derive a simplified model of the crustal structure and the Moho topography. The model is based mainly upon results from FENNOLORA, EUGENO-S, and EUGEMI projects as part of the European Geotraverse (EGT) as well as BABEL, MONALISA, and a few smaller projects. The derived Moho interface contains the same basic features of previous Moho maps. Traveltime contributions of 3D crustal structure are calculated from this 3D crustal model to correct observed teleseismic traveltimes for local crustal effects. The remaining relative traveltime residuals will be interpreted in terms of lateral inhomogeneities in the lower lithosphere and the topography of the lithosphere-asthenosphere boundary. Areas with similar traveltime residuals allow to filter out erroneous phase identifications and correlations and thus reduce error in the data.

CRUSTAL STRUCTURE OF THE NE-GERMAN BASIN, INFERRED FROM GEOLOGICAL AND GEOPHYSICAL DATA AND MODELS

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The NE-German Basin is part of the so called Southern Permian Basins along the TESZ. The Permian thermal event almost certainly affected the upper mantel and the lower crust and, therefore, may have modified the 'crustal memory' with regard to Caledonian and Variscian events. Additional tectonic events affected the area during the Mesozoic and a sedimentary sequence of up to 8 km thickness accumulated since the late Paleozoic, covering key areas of the TESZ.
Here we report about the attempt to integrate a variety of geological and geophysical data in order to reveal at least the present day deep crustal structure of the NE-German basin. Based on geological and geophysical data, which have been provided by the oil-industry in East Germany, and by the deep seismic line BASIN'96, shot by DEKORP in 1996, an interdisciplinary and interinstitutional attempt is made to integrate all available data into a concise model. Special focus will be taken at the detailed geological information, the available reflection seismic data, gravimetric and magnetic data, and last not least the wide angle refraction seismic data concerning the deep crustal velocities.

TOR - TELESEISMIC INVESTIGATION OF THE TRANSEUROPEAN SUTURE ZONE

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The EUROPROBE project TOR-1 is a teleseismic investigation of the northern section of the Transeuropean Suturezone (TESZ). The TOR-1 profile is 900 km long reaching approximately from Bielefeld (Germany) to Stockholm (Sweden). It crosses prominent tectonic features of Central and Northern Europe such as the Sorgenfrei-Tornquist Zone, the North German-Danish Basin, the Caledonian Suture and the Lower Elbe Lineament. During the main phase of data acquistition, from Oct 96 to April 97, approx. 120 mobile seismic recording units were in the field, 30 broadband stations even for more than one year. The spatial tomographic resolution will be in the order of 20-30 km. To the east the area of investigation is bounded by the most recent DEKORP profile BASIN 96 providing seismic velocities and near vertical reflection imaging of deep crust of the NE German Basin. The DEKORP measurements are an excellent basis for integrating detailed crustal information and teleseismic measurements. We present first results based on selected teleseismic events and crustal seismic investigations.

ANISOTROPY ACROSS THE TESZ FROM SHEAR-WAVE SPLITTING

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During the TOR-1 passive seismic experiment in 1996/97 a maximum of 133 temporary seismograph stations were operating over the Sorgenfrei-Tornquist Zone (STZ) in an area extending from northern Germany to central Sweden. Of the 133 stations, 29 were equipped with broad-band seismometers. One of the objectives of the experiment is to study horizontal anisotropy directions in the subcrustal lithosphere and asthenosphere across the Trans European Suture Zone. To achieve this goal, broad-band data from the TOR stations and additional stations of permanent networks were analyzed for splitting of SKS phases. As a result of the dense station spacing, the method offers good lateral resolution of anisotropy. Preliminary results suggest that the directions of the fast horizontal S wave velocity are affected by the STZ. In central Europe and southern Sweden, far away from the STZ, fast S wave directions are approximately E-W while they turn more northerly closer to the STZ. Our observations may indicate that mantle flow in the asthenosphere is deflected at depths greater than 100 km beneath the STZ.

THE VARISCAN BELT IN CENTRAL EUROPE: GEOLOGY AND GEOPHYSICS

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The Variscan belt of Europe is a collage of microplates (Avalonia, Armorican archipelago) set between Laurentia, Baltica and Gondwana mainland. The geological record reveals important crustal extension in Cambrian and Ordovician times, subduction of separating oceans from the Silurian onwards, and collision during the Late Devonian. Collisional shortening took place in a regime of (mostly) dextral transpression. Orthogonal shortening amounts to at least 700 km.
Plate boundaries are steeply inclined, and well-defined, even under younger cover, by sharp magnetotelluric anomalies. The DEKORP grid of high-resolution reflection seismic lines permits structural analysis in 3D. In the Rhenohercynian foreland fold & thrust belt, crustal extension was more pronounced E of the River Rhine than in the W (Ardennes). This resulted in a more thick-skinned tectonic regime in the E. Seismic profiles across the Rhenohercynian belt reveal the contrasting styles of deformation, as well as tectonic underplating, antiformal stacking and backthrusting in the orogenic hinterland (Mid-German Crystalline High). In the Saxothuringian belt adjacent to the SE, seismic profiling has yielded superb evidence of long-distance transport of thin-skinned thrust sheets. Recent profiles reveal a laterally persistent metamorphic core complex in the Saxothuringian subsurface, exposed the Saxonian Granulite antiform. The granulites were probably emplaced by extrusion from the hot orogenic root to the SE.

REMAGNETIZATION OF DEVONIAN CARBONATES FROM THE HOLY CROSS MTS (CENTRAL POLAND).

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Paleomagnetic studies of the Middle-Upper Devonian carbonate rocks in the Holy Cross Mts (HCM) were carried out. Oxidized rocks containig goethite and hematite (10% of collection) revealed the presence of post-folding remagnetization of the Late Carboniferous/Early Permian age. The poles of these components are situated on the apparent polar wander path (APWP) of the Old Red Continent. In the remaining part of the collection magnetite/maghemite and magnetic sulphides were dominant magnetic minerals. The age of magnetization was synfolding in one locality and either pre- or synfolding in four others. The poles of these components are shifted to the NW from the reference Old Red APWPs. Our data could point to the Variscan mobilism of the entire HCM area which could be either rotated clockwise or displaced along the dextral strike-slip fault along the SW edge of the East European Platform. in the time between Early Devonian and Early Carboniferous. This model would require a significant (10-30 Ma) diachronism of Variscan folding in some parts of the HCM which is so far not supported by geological observations. Therefore an alternative explanation is suggested that pre- and/or synfolding components could be strain modified magnetizations and they should not be used for paleotectonic reconstructions.

The TransEuropean Suture Zone in NE-Germany - Implications and constraints from structural studies, provenance analysis and isotope dating

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Palaeomagnetic results (Torsvik et al., 1992, 1996) show that Baltica and Gondwana were separated by a wide Tornquist Ocean in Early Palaeozoic times. Thus the origin of the TransEuropean Suture Zone (TESZ) can be seen in the closure of the Tornquist Ocean during Caledonian times.
The most representative section across the TESZ including the Tornquist-Teisseyre Zone (TTZ), the Caledonian Deformation Front (CDF) and the TransEuropean Fault (TEF) can be found between Bornholm (in the southern Baltic Sea) and NE-Germany.
Structural investigations of core material characterize the Caledonian deformation. Provenance analysis and isotope dating of Palaeozoic clastic sediments help to address each structural domain to its crustal origin. In combination with the recently shot DEKORP-profile a thorough interpretation of the deeper subsurface of the southern Baltic Sea and NE-Germany appears possible.

EUROBRIDGE-95: DEEP SEISMIC PROFILING WITHIN THE EAST EUROPEAN CRATON

EUROBRIDGE Seismic Working Group

The EUROBRIDGE deep seismic sounding profile is part of a EUROPROBE project to examine Palaeoproterozoic processes of continental collision and crustal accretion. The purpose of the seismic profile is to establish the deep lithospheric structure of the East European Craton between the exposed Archaean and Proterozoic complexes of the Baltic and Ukrainian shields, with particular interest in the contact zone between Fennoscandia and Sarmatia. The thickness of the Phanerozoic sedimentary cover decreases from 2.2 km in the northwest at the Baltic Sea coast to 0.3 km in the southeast end of the profile near to the Lithuania - Belarus border. Crustal thickness varies from about 44 km in the northwest and central part of profile, increasing to about 50 km in the southeast. Crystalline upper crust is about 20 km thick, thinning in the southeast, with P-wave velocities of 5.9-6.3 km/s. A very weak low velocity zone, with a velocity contrast of 0.1-0.2 km/s, occurs at 8-13 km depth below the northwest and central part of the profile only. Lower crust velocities are generally 6.5-6.9 km/s. It thickens in the southeast, where P-wave velocities of up to 7.05 km/s occur in its deepest parts. Very strong reflections from the Moho boundary are observed. The mantle P-wave velocity immediately below the crust is 8.2-8.35 km/s. A reflector in the lower lithosphere at a depth of almost 70 km was found below the central part of profile.

BALTIC SHIELD EDGE TELESEISMIC TOMOGRAPHY, PROJECT TOR

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The data of the largest seismic antenna ever in Europe is now in hand for interpretations of the deep lithosphere across the Tornquist Zone. The project is part of Europrobe. It crosses the Trans-European Suture Zone with **markedly different crustal domains** in Germany, Denmark and Sweden. In previous deep geophysical studies it was demonstrated that the lithosphere contrast is significant. The aim of the project is to **delineate in fine scale how the transition occurs**, for geological unravelling of the history. The Tor project has a **horizontal resolution of 20-30 km** compared to more than 100 km in the previous studies. The investigation includes **P-wave** teleseismic travel-time tomography plus **S-wave tomography**, **anisotropy** and **many inversion methods**. The Tor line goes along a well studied crustal profile of an earlier project, so that sediments and crustal structure are assumed known, and the inversion efforts are concentrated on the deep lithosphere and asthenosphere differences to depths around 300 km. The investigation can be called 2½ dimensional, being a 900 km profile with 100 km width plus a few seismographs off the profile. 120 seismographs were in the field for ½ year in 1996 - 1997. We see clear differences from one end of Tor to the other, but the tomographic inversions are still in preparation.

NEW INTERNATIONAL SEISMIC PROJECT IN THE EUROPROBE TESZ / PANCARDI PROGRAMME

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One of the major tectonic problems in Europe concerns the southwest margin of the East European Platform. In general, this margin assumed to be the Tornquist-Teisseyre Zone (TTZ), running across Europe approximately from north-west to south-east. The Polish segment of TTZ is a part of the Trans European Suture Zone (TESZ), a first order geotectonic unit, stretching from Black Sea to the British Islands. Determination of deep crustal structure of the contact zone between the Precambrian Platform, the Palaeozoic Platform and Carpathian Mts was the main aim of the deep seismic sounding programme in SE Poland in 1965 - 1982. In the study area the crustal thickness varies, being 48 km within the Precambrian Platform, about 55 km in the TTZ, about 45 km in the Holy Cross Mts and 30 - 35 km in the Palaeozoic Platform. In the framework of the new programme of deep geological investigations in Poland there are proposed for the SE Poland and Carpathian Mts new DSS refraction and wide angle reflection profiles and near vertical reflection profiles with a total length of about 2500 km. The proposed program will be correlated with EUROPROBE PANCARDI Project in Carpathian Mts and Pannonian Basin.

POLONAISE'97 - INTERNATIONAL SEISMIC EXPERIMENT BETWEEN PRECAMBRIAN AND VARISCAN EUROPE IN POLAND

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The Permian - Mesozoic Basin in Poland forms the most eastern part of the Permian - Mesozoic Central European Basins, bordered from the east by the East European Craton (EEC) and from the southwest by the Bohemian Massif. The axis of the Basin, called the Mid - Polish Trough (MPT), parallels the edge of the EEC, along the boundary between the Phanerozoic and Proterozoic European crustal domains. The Polish Trough coincide approximately with the Tornquist - Teisseyre Zone (TTZ). The Polish segment of TTZ is a part of the Trans - European - Suture Zone (TESZ), a first order geotectonic unit, stretching from Black Sea to the British Islands. A large seismic experiment, just completed in Poland, targeted the deep structure of the TESZ and the complex series of upper crustal features associated with it. This international cooperative effort, is known as POLONAISE'97 Project. The final experiment is perhaps the largest entirely land-based lithospheric seismic experiment ever undertaken, with over 600 instruments being deployed to record 63 shot points along 5 profiles with a total length of more than 2000 km. Moreover, 5 multichannel seismic reflection stations (120 channels) recorded all shots.

TELESEISMIC P-CODA STUDIES ALONG THE TOR-PROFILE

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During the international project TOR-1 (Teleseismic **TO**mography **TOR**nquist) the largest seismic network ever installed in Europe was set up in summer 1996 across the northern segment of the TESZ and operated for a one-year period. It consisted of up to 108 SP and 31 BB three component stations which recorded continuously covering an area of approximately 1000 km length and 100-200 km width stretching between northern Germany and southern Sweden.
Our aim is to determine the small scale random structure of the crust and upper mantle across the TESZ by studying the time and frequency behaviour of the coda following the direct P arrival. From the TOR data set all teleseismic events with depth greater than 50 km, magnitude $m_b \geq 5.8$ and high signal to noise ratio in the whole time window of the P coda have been selected. Typical coda envelopes along the profile will be shown. Correlation lengths and rms velocity fluctuations have been inverted from the time and frequency behaviour of the coda envelopes after the P onset using a modified energy flux model. The first trial of mapping the statistical parameters with their lateral and depth dependent variation along the whole profile will be presented.

CRUSTAL STRUCTURE FROM SEISMIC NEAR VERTICAL REFLECTION DATA IN THE POLISH BASIN

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The results of deep seismic soundings by the near - vertical profiling method made in the Polish basin, north-western Poland, are presented. In 1995 - 1996, along a few commercial seismic reflection profiles deep crustal structure study were made. The recording time was extended up to 18s and the charge of some shot points were enlarged to 10-15 kg of TNT. The total length of profiles was about 200 km. The recording system adopted ensured a 48-fold coverage of the profile in the common depth point (CDP) method. On the seismic sections two sequences of reflected waves are clearly visible.The first occurs in the 0 - 2,5 s interval and is associated with seismic boundaries in the upperpart of sedimentary cover. The other sequence of reflected waves is contained in the 8 -12 s interval and is related to seismic structure of the middle and lower crust, and the transmition zone between the crust and upper mantle. Depth of the Moho discontinuity is 30-33 km. The analysis of seismic velocities shows relatively low velocities up to about 20 km depth, being lower than 6.0 km/s. This fact is discussed together with other seismic results of this region - from seismic refraction and wide angle reflection profiles and the surface waves study.

CRUSTAL STRUCTURE FROM DEEP SEISMIC REFRACTION AND WIDE ANGLE REFLECTION EXPERIMENT IN THE TEISSEYRE TORNQUIST ZONE IN POLAND (TTZ PROFILE)

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New seismic refraction and wide angle reflection experiment in the Teisseyre - Tornquist zone in Poland was made in July 1993 as an international Polish, Finnish, German and Swedish cooperation. The profile is located exactly in the central part of the Mid-Polish Trough in the zone of maximum subsidence (starting from the Upper Permian until the Upper Cretaceous). The length of the profile was about 450 km. Nineteen shot points were located along profile. The distance between shot points was about 25 km. Recording was made using 135 three-components modern seismic stations, with spacing of the recording sites about 2 km. Depth of the consolidated basement, with velocity about 5.8 km/s in this area is 8 to 10 km. However, down to a depth of 15 - 20 km P - wave velocity is very low, no more then about 6.0 km/s. Thickness of the crust varies from 35 to 45 km. We discussed them together with other seismic results of this region - from deep seismic sounding profiles, deep reflection profiles and with results of the surface waves study.

A DETAILED SEISMIC VELOCITY MODEL OF THE PALAEOZOIC PLATFORM IN NW POLAND

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POLONAISE profile 1 is subparallel to the Teisseyre – Tornquist Zone (TTZ) in the Trans-European Suture Zone in NW Poland. The purpose of this ~300 km long profile is to obtain a detailed model of seismic velocity by reducing structural influence and, thereby, also to provide a reference seismic structure for future modelling of two other POLONAISE profiles across the TTZ. 11 in-line shots were recorded at 100 stations deployed with an interval of ~3 km.
Preliminary modelling shows that compressional velocities are very low (<6.1 km/s) to ~20 km depth above a high velocity (≥ 6.8 km/s) lower crust which is strongly reflective. Strong P_MP reflections are observed everywhere along the profile corresponding to a crustal thickness of ~30 km. The seismic model has implications for Caledonian and Variscan collision tectonics and for subsequent basin formation in the area.

A SUMMARY OF CRUSTAL STRUCTURE ALONG THE APPALACHIAN-OUACHITA OROGENIC BELT IN NORTH AMERICA: A COMPARISON WITH THE TESZ

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The Appalachian - Ouachita orogenic belt represents the extension of TESZ structures into North America. In the northern Applachian region, the LITHOPROBE program in Canada has provided significant new results, and in the US, several modern studies have been completed in New England region. These studies show that the crustal scale deformation is considerable and that the crustal thickness of the Avalonia Terrane is about 35 km. In the central and southern Applachian region, the only modern deep seismic data come from reflection profiles which generally do not image the Moho well. However, gravity and time-term data indicate that the crust may be up to 50 km thick in the central Appalachians. In the southern Appalachians, the crustal thickness is about 40 km, and the crustal scale deformation may not be as intense as in the north. A PASSCAL experiment was conducted in the Ouachita Mountain region in 1986. This wide-angle profile partially overlapped a COCORP profile, and together, these data provide a good picture across the orogenic belt. The early Paleozoic continental margin is preserved beneath Ouachita thrust sheets indicating that crustal scale deformation was mild. A zone of transitional or oceanic crust is found south of the orogen, and a microcontinent is found outboard of this zone. Based on the limited geophysical data available, similar pictures of crustal structure appear to be present along the other segments of this orogenic belt.

THE NORTHERN RIM OF THE CENTRAL EUROPEAN BASIN SYSTEM - THE OFFSHORE-ONSHORE SURVEY *BASIN '96*

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The North German Basin is an intracontinental basin of hotly debated geodynamic evolution, extending from the Tornquist Zone -an inferred Paleozoic suture- to the Harz Mountains, and from the North Sea to Poland. The basin is a complex one with various geophysical anomalies, magmatic intrusions and several changes in tectonic and subsidence regime over the past 300 Ma.
In 1996, DEKORP organized the project *BASIN '96* to perform *B*asin *A*nalyses and *S*eismic *I*nvestigations in *N*orth Germany. The seismic data were gathered as a combination of 800 km reflection line offshore (airgun array) and 500 km onshore (vibroseis and explosive) to run a complete line through the entire basin and across its margins.
Initial results reveal the offshore continuation of fault structures already mapped onshore, sedimentary inversion structures, the Moho depth, and deep crustal and upper mantle structures. These images lead in correlation with older seismic data to the location of the Caledonian Deformation Front in the investigated area, and to the discussion of terrane boundaries north of the Tornquist System.

VARISCAN TO ALPINE PALEO-STRESS EVOLUTION IN THE TEISSEYRE-TORNQUIST ZONE (SOUTHERN POLAND)

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In Southern Poland we measured micro-structures and did field structural analysis in rocks ranging in age from Cambrian to Miocene, in order to compute paleo-stress field (Angelier's method). Investigated areas are: Holy-Cross Mts., Radomsko Elevation, Czestochowa and Krakow regions.
A N-S compressional Variscan stress pattern was provided in the Holy Cross Mts. It is marked by folds and associated brittle structures. The polyphased deformation resulted in complexe fold structures (early ramps and brittle deformation before folding) showing sequencial relationships.
This period was followed by a general extensional stress regime leading to the development of the Polish Trough parallel to the Teisseyre-Tornquist Zone. The basin geometry was influenced by major NW-SE and NNW-SSE basement faults.
The Laramide tectonic inversion was marked by a NE-SW compression in the Mesozoic cover of the Holy Cross Mts. and in the Radomsko Elevation, linked with a reactivation of the NW-SE and NNW-SSE basement faults. The Czestochowa region was not deformed. In the Krakow region, a N-S compression is dated as Miocene and related to the Carpathian front.

STRUCTURAL AND PALEOMAGNETIC DATING OF TECTONIC-RELATED FRACTURE FILLS

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This study was carried out in the Holy Cross Mountains, the Paleozoic Massif adjacent to the Teisseyre-Tornquist Zone and structurally incorporated to the Epi-Variscan Platform of southern Poland.
Upper Paleozoic rocks exhibit fractures trending about N-S showing a four stage sequencial history: (1) they originated in a late variscan tectonic stage, occured after the major folding. The fractures show successive openings marked by (2) calcite fibers and (3) Late Permian - Early Triassic red sediments filling, evidence for first stages of rifting in the Polish Trough. This Buntsandstein type sedimentary filling is affected by (4) dextral strike-slip slicken-slides compatible with the Laramide tectonics.
Paleomagnetic studies enabled for recognition of four generations of paleomagnetic components that could be dated by comparison with APWP for Baltica, yielding generally the late Variscan, early-post Variscan and Alpine magnetization ages. Since fractures fillings are associated with the fracture openings, the paleomagnetic method could be used for dating of related brittle tectonic, at least for constraining its upper age limit.

VARNET: A GEOPHYSICAL STUDY OF THE VARISCIDES AND CALEDONIDES IN SW IRELAND

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To investigate the influence of the Variscan and Caledonian orogenies on crustal structure in SW Ireland, three wide-angle seismic profiles were recorded as part of VARNET, an international co-operative project. Data were collected along two approximately north-south profiles about 80 km apart. The station spacing was about 1000 m on the eastern profile and 800 m on the western one. The third line was a short splay line NE from the middle of the western line. A total of 34 shots were fired, 23 of which also served as off-line fan shots.
The seismic models from both profiles show that major Variscan features in the south west of Ireland are limited to the upper crust, indicating a thin-skinned mechanism of deformation. Deeper structural changes on the eastern profile can be related to the Iapetus Suture Zone, which is crossed in the vicinity of the Shannon River Estuary. The total crustal thickness varies from 29 to 32 km, with upper mantle velocities significantly lower south of the Shannon.
Crustal structure between the two profiles, and to the west of them. can be derived with data from fan shots, giving three-dimensional information on the crustal structure of the Variscides and Caledonides in SW Ireland.

The place consistency of the Tornqust Zone in geological time.

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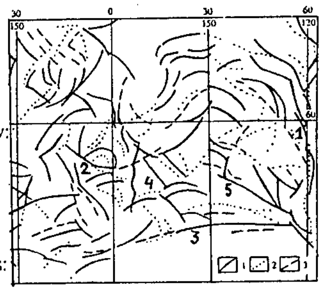
Compare part of Atlantic(A) and Pacific(P) hemispheres structures. **Fig.** shows their global axial symmetry **[1]**. Geminy are 1=Urals-Timan/Pz/,Cordilleras-Alaska/Mz/; 2=Walles oval/Pz/,Bowers arc /Kz/; 3=seems Apsheron-Atlas, Mendocino /Mz/. Lines overlap show: they were on their places all time. Images of TESZ, Donbass are 4=Blanco-Chinook Fr.z, Gemini ridge, 5=isl.Kodiak-Bowie. Old ocean hystory is dreamy. Twins Cordilleras-Urals say: the places of seems are permanent. To resign the mobilism it is enough to know: cover lavas are final acts at cyclic fold arcs rears. In the ocean centers arcs collide.



[1] G.Makarenko (1993) M.Cosmoinform. 280 p.

Fig. Both hemysphere seems: 1-A,P; 2-A only; 3-P only

COMPOSITION, STRUCTURE AND EVOLUTION OF PRECAMBRIAN CRUST: EVIDENCE FROM VP/VS RATIOS

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Recently, much attention has been paid to the composition and evolution of the crust and sub-crustal lithosphere in cratonic regions. Some of the key issues are whether there is a compositional difference between Archean and Proterozoic lithosphere, and whether Precambrian lithosphere is distinct from phanerozoic lithospere. Attempts to address these questions using only the compressional-wave velocity structure have met with limited success, leading to considerable debate in the scientific literature.

Here we revisit this question using Vp/Vs ratios rather than simply Vp. Previously, this approach was only possible for territory of the former Soviet Union, where numerous Vp/Vs measurements have been reported. Our new compilation of average crustal Vp/Vs ratios indicates a strong dependence on crustal age, with Archean and Phanerozoic crust have a relatively low value of 1.74, whereas Proterozoic crust ranges from 1.77-1.84.

We conclude that Proterozoic is more mafic in composition than other crust, and that Paleozoic terrains, such as Caledonian orogen and the vast Altaids of Central Eurasia have not evolved to have a composition similar to Proterozoic crust. Archean crust is distinct from Proterozoic crust, having developed a thick lithospheric keel early in its evolution.

GEOLOGICAL DEVELOPMENT OF THE NE GERMAN BASIN

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The NE German Basin (NGB) is an intracratonic basin containing in excess of 12 km of Phanerozoic strata. It is part of a series of related basins extending from the North Sea to Poland. Four broadly NW-SE-striking fault zones occur in the area. From north to south these are: the Tornquist Zone (TZ), the Caledonian Deformation Front (CDF), the Trans-European Fault (TEF), and the Elbe Line (EL). The region was significantly influenced by the Caledonian and Variscan orogenies.

Crustal warping and block faulting in the Upper Carboniferous was followed by a major magmatic episode which extended up into the Lower Permian. This resulted in a thick volcanic succession of Permosilesian age. Initial basin subsidence, appears to have occurred without significant fracturing of the upper crust, since no normal faults with large vertical offsets have been observed. However, geochemical analysis of the volcanics indicates thermal destabilisation of the crust prior to initial subsidence.

The newly-obtained seismic data (DEKORP/BASIN 96) from the NE German Basin provide the basis for a detailed examination of the geodynamic evolution of the region. This, together with a variety of borehole and industrial seismics, was used to correlate the broad structural and stratigraphic framework for the region. Further aims include the development of a series of basin models derived from seismic and sequence stratigraphic analysis.

THE TRANS-EUROPEAN SUTURE ZONE: A TECTONIC OVERVIEW

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The Trans-European Suture Zone (TESZ), the most prominent geological boundary in Europe, separates mobile Phanerozoic terranes (Caledonide-Variscide orogens) in the SW, from the ancient Precambrian crust of the East European Craton (and Baltic Shield), over a distance of 2000 km. In the North Sea and N Germany, crust of Avalonian affinity is juxtaposed with the Baltic Shield along the southward- dipping Caledonian Deformation Front. The presence of late Ordovician arc magmatic suites in the Anglo-Brabant Massif and their absence in the shield indicates the destruction of the Tornquist Sea by southward-dipping subduction, although the geophysical evidence is equivocal. Docking of Avalonia against Baltica occurred in latest Ordovician or earliest Silurian time, with further oblique-slip during early Devonian deformation.. In central Europe, the suture is obscured by overriding orogenic complexes in the west (Variscides) and east (Carpathians). As a result, the evidence for the early Palaeozoic history of the TESZ here is difficult to decipher. In SW Poland, the juxtaposition of Neoproterozoic crust of Cadomian type with the East European Craton at the Kraków-Lubliniec Zone indicates that the Avalonian terrane has been replaced by proto-Gondwanan crust with a very different early Palaeozoic history, which may not have been accreted until Devonian time. Thus the TESZ has a complex history and is certainly composite in origin. EUROPROBE geophysical experiments aim to characterise lithospheric structure in the contrasting segments of the zone.

CALEDONIAN AND OLDER TERRANE ACCRETION IN THE SOUTH-WEST BALTIC SEA

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During a marine seismic survey by BGR-Hannover and DEKORP,Potsdam in 1996 a number of profiles were arranged in the SW-Baltic Sea. The objective was to gather convincing evidence for the structure of the Caledonian Deformation Front (CDF) and for other terrane accumulations in Baltica. Previous reflection lines, like BABEL and several exploration lines, were intergrated in our interpretation. As was suspected already from the BABEL results, the CDF was found to be a bi-vergent collisional zone, the upper crust from Avalonia ovethrusting the rim of Baltica toward the E or NE, but the subduction of the Tornquist Ocean also directed toward N or NE, as seen by many N-NE dipping reflections in the uppermost mantle. Another interesting structure is a Proterozoic terrane accretion NE of Bornholm. Here, extremely dense and strong, divergent reflections in the crust indicate overthrusts and indentations along shear zones in the whole crust. Other observations of troughs and inversion zones help to reveal the architecture and evolution of crust and upper mantle in the area around the TESZ in the Baltic Sea.

DEKORP BASIN 1996: RECENT RESULTS OF THE SEISMIC WIDE-ANGLE MEASUREMENTS

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The DEKORP BASIN 1996 survey focussed on the structures of the North German Basin and of the southern Baltic Sea. The seismic signals of the near vertical reflection profiling were also observed in "piggy-back" mode at wide-angle distances. Whereas the airgun-shots of the Baltic Sea survey were recorded at fixed single stations on land a "roll-along" experiment was carried out along in the North German Basin profile in addition to measurements at some fixed stations.

The quality of the Baltic Sea data varies strongly depending on the position of the station. In the the North German Basin the data shows less signal/noise-ratio in the center of the basin than at its margins. We applied dip filters in order to improve the S/N ratio.

On the basis of a velocity-model for the post Zechstein-sediments and traveltimes of near vertical and wide-angle reflections a two-dimensional velocity model of the North German Basin was determined and extrapolated into the Baltic Sea area. In the center of the North German Basin the Moho is flat and approximately 31 km deep. It does not deepen significantly at the northern margin of the basin. The average p-wave velocity between Zechstein-basis and Moho is 6.5 km/s. At the basin center the p-wave velocity of the lower crust is 6.7 - 7.0 km/s.

CRUSTAL STRUCTURE ONSHORE AND OFFSHORE IRELAND: DEVELOPMENT FROM PALAEOZOIC TO RECENT TIME

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Recent onshore and offshore seismic data have helped to provide a model for the development of the crust from Palaeozoic times. This involves crustal thickening along vertical and horizontal features, and crustal thinning along inclined and horizontal detachments.
The three-layer crust beneath Ireland is approximately 30 km thick and is thinner beneath offshore sedimentary basins. Whole crustal thickness and structural changes through central Ireland are attributed to continent/continent collision which formed the Caledonian Iapetus Suture. Upper crustal thickness differences in the south of Ireland (onshore and offshore) are due to both Variscan thick- and thin-skinned thrust tectonics with local structure influenced by heterogeneous Caledonian crust. Severe thinning of the crust beneath large Mesozoic sedimentary basins is attributed to differential stretching influenced by rheologically-controlled intra-crustal detachments.

POLONAISE'97 - SEISMIC STRUCTURE OF THE PRECAMBRIAN CRUST OF EASTERN EUROPE ALONG P3 PROFILE

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The Precambrian Platform of eastern Europe includes the northeastern part of Poland. The East European Platform (EEP) is the oldest tectonic unit in concern. Its basement was formed during Archaean and Proterozoic times, and was consolidated during the Subjotnian - Jotnian cratonization. The 305 km long refraction and wide angle reflection P3 profile is located on the Precambrian Platform in northeastern Poland, parallely to the southwest boundary of the EEP. Seismic measurements were made in May 1997 in a framework of international seismic experiment POLONAISE'97 Project. There were eleventh shot points on the P3 profile with distances between them 25 - 30 km. All shots were fired in boreholes. An average station spacing was about 2 km. They have got seismic refraction and wide angle reflection data of good quality with clear first impulses and later phases in the whole interval of distances maximum up to 305 km from the shot points. Thickness of the sedimentary cover changes along P 3 profile from 2 km to 7 km. Moho discontinuity with velocity 8.1 km/s was found at the depths 42 - 45 km.

DEEP STRUCTURES IN DANISH SEDIMENTARY BASINS

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The formation of the Norwegian-Danish Basin, was mainly caused by Carboniferous-Permian rifting, probably with a main phase in the Autunian accompanied by extensive volcanic activity. The Top Pre-Zechstein reflector separates syn- and pre-rift sediments from post-rift sediment. The extensive faulting accompaning the formation of the Norwegian-Danish Basin is thus found below the Top Pre-Zechstein reflector, and only few of these faults continued to be active in Mesozoic times. The Ringkbing-Fyn High was also formed at this time as a zone suffering less extension that the central parts of the basin. The pre-rift succession is mainly constituted by Caledonian foreland basin deposits of mainly Silurian age, which attain thicknesses in the order of 4 kilometers. Evidence from reflection seismic data suggests NE-SW compression along the southern border of Baltica during the Caledonian orogeny.

TELESEISMIC AND LOCAL EVENTS RECORDED DURING POLONAISE'97 - DATA AND PRELIMINARY INTERPRETATION

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Twenty Polish short-period three-components stations were continuously operating for three weeks during POLONAISE'97 in the contact zone between Palaeozoic and Precambrian platforms in Poland. The distances between the seismometers were about 20 km and the digitization interval 0.02 s. The records perform except the shots also a few teleseismic and local events. Interpretation of traveltime and amplitude anomalies for direct P phase can result in some information about the structure beneath the stations useful for farther tomography investigation.

EUROPEAN POTENTIAL FIELD DATA AND THEIR TECTONIC IMPLICATIONS

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Gravity and magnetic surveys have been completed over most of Europe during the past fifty years and maps have been published by individual countries. However, the TESZ project has highlighted the need to establish a common, non-commercial, database of potential field data from western and eastern Europe for the benefit of TESZ research and the geoscience community in general. During the past year considerable progress has been made on a collaborative venture to bring together the various data sets, resulting in new gravity and magnetic compilations covering the TESZ and surrounding regions. New image maps of potential fields have been generated as part of the ongoing effort towards these compilations which show both continental-scale and local-scale structures. The maps are particularly effective at highlighting the tectonic framework of Europe formed during Laurentia-Baltica-Avalonia collision as well as new evidence on the position of the concealed margins of the palaeo-continents at depth.

SE20 Aspects of the Carpathian-East Alpine-Pannonian geodynamics: the PANCARDI approach

Convener: Tomek, C.
Co-Convener: Neubauer, F.

SUMMARY OF PALEOMAGNETIC AND STRUCTURAL DATA FROM THE CENTRAL WEST CARPATHIANS OF POLAND AND SLOVAKIA: EVIDENCE FOR THE LATE CRETACEOUS-EARLY TERTIARY TRANSPRESSION.

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The paper presents the review of paleomagnetic and structural data from the Central West Carpathians (CWC) of Poland and Slovakia. The CWC constitute a multiply deformed thin skinned fold and thrust belt adjacent to the Pieniny Klippen Belt. Mesozoic sedimentary rocks of the CWC were subjected to the remagnetization which took place ca 90 Ma during the Late Cretaceous thrusting. In most localities moderate clockwise rotation of paleomagnetic declination (about 30°) is observed. Clockwise rotation of the CWC could take place after Late Cretaceous and before Eocene. In contrast paleomagnetic declinations from the Eocene-Miocene rocks of the area reveal counterclockwise-rotations. Structural data obtained in the Pieniny Klippen Belt point to abrupt change in the paleostress field at the Late Cretaceous/Paleogene boundary. Change of both paleomagnetic declinations and stress fields could indicate a large dextral rotation of the CWC due to oblique convergence during Cretaceous-Early Tertiary.

LITHOSPHERE STRUCTURE IN THE WEST CARPATHIAN-PANNONIAN-EAST CARPATHIAN TRIPLE JUNCTION AREA BASED ON GEOPHYSICAL DATA

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For better perspective of the present lithosphere structure in the West Carpathian-Pannonian-East Carpathian triple junction area geophysical interpretation is done. Interpretation of gravity field is based on local isostasy and forward density modelling. The results demonstrate a slab underneath the mountain range. The slope of the underthrusted lower European platform is very steep. Modelled slab dips from about 60 to 80 degrees. The southern margin of the European basement bends down to the southwestern into the Carpathian subduction system. Analysis of geophysical data along profile C indicates that interaction of compression, transpression and extension can be observed in the studied area. This interplay led to formation of the East Slovakian Basin, too. The basin is characterized by larger thickness of sediments and both crustal and lithospheric thinning. Extensional process was accompanied by updomming of high-density mass into the lower crust. In this region transpression influence is very intense. As a result older structures of upper plate were segmented and originally independent fragments are in connection recently (Zemplín Unit, Iňačovce-Krichevo Unit, blocks of rifted European platform, the Carpatho-Pannonian block). On the contact of the upper and lower plate "flower" type structures are prevalent.

THE STRESS FIELD OF THE COLLISION-SUBDUCTION ZONE IN SE-ROMANIA

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The Vrancea region (Romania) in the SE-Carpathians is a complex tectonic zone dominated by a continental collision between the East-European Platform, the Moesian sub-plate and the Tisia-Dacia block. Todays seismicity is characterized by repeated strong earthquakes ($M \leq 7.7$) in intermediate depths (70–180 km) with a gap in earthquake occurrence between 40 and 70 km. In this study we investigate the regional and local stress orientations and tectonic regimes based on the analysis of fault slip investigations, borehole breakout data and fault plane solutions of earthquakes. We found that the earthquakes with a focal depth $\leq$ 40 km comprise an epicentral area bounded to the northeast by the Trotus Fault, and to the southwest by the Sinaia and the Intramoesian Fault. These crustal events do neither show a dominant tectonic regime nor a well-confined direction of the maximum horizontal stress orientation. The intermediate depth earthquakes show dominantly thrusting, but also do not indicate a dominant direction of maximum horizontal stress. One aim of this study is to obtain a more detailed 3-dimensional zonation of stress domains which can be correlated and compared with the overall seismicity and the regional tectonics of the study area. Furthermore an estimation of the seismogenic potential of the different units will be given.

LITHOSPHERIC THERMAL STRUCTURE IN THE TRANSYLVANIAN DEPRESSION — INSIGHTS FROM NEW GEOTHERMAL MEASUREMENTS AND MODELING RESULTS.

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The surface heat flow density pattern of the Transylvanian Depression (TD) represents a marked high amplitude short wavelength low in a region of generally elevated heat flow. Detailed temperature-depth profiles obtained by continuous temperature logging in 24 wells to a maximum depth of 1400 m combined with a finite element modelling of topographic and fluid flow effects support the conclusion that the observed thermal gradient in the TD truly represents the rate of heat loss of the subsurface. Modelling results show that the transient effects of sedimentation and erosion mean an overall 5-7 mWm^{-2} reduction in heat flow compared to the steady-state value and that a low mantle heat flow and a low crustal heat production rate in the TD are necessary to explain the heat flow anomaly. The effect of the Neogene evolution of the TD on the temperature filed of the lithosphere is evaluated as well.

Pannonian Basin Syn- and Post-Rift Evolution; Dynamic Modelling of the Transition from Passive to Active Rifting.

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The first order features of the Pannonian basin are predicted and explained using a thermo-mechanical finite element model of lithosphere extension and simple physical reasoning. We show that active mantle upwelling following a phase of passive extension are viable mechanisms explaining the Pannonian basin formation. The dynamic interplay between far-field driven passive extension and active thinning of the mantle lithosphere by convective upwelling beneath the rift zone is modeled using thermo-mechanical finite element methods. Thermal buoyancy, related to the syn-rift asthenospheric doming drives active upwelling in a lithospheric scale convection cell. In this way horizontal stresses are generated which compete with the far-field intraplate stress. In the late syn-rift or early post-rift stage, domal forces may dominate and even drive the system causing a change from passive to active rifting mode. If this transition occurs, the numerical model predicts 1) drastic increase of sub-crustal thinning beneath the rift zone, 2) lower crustal flow towards the rift flanks, 3) the coeval occurrence of tensional stresses within and compressive stresses around the upwelling region, 4) significant decompression melts, 5) possible surface uplift. The model predictions may explain several poorly understood observations that characterise the Pannonian basin. E.g. the observed strong differential thinning, intermediate crustal extension, $\delta \approx [1.6\text{-}1.8]$ and strong thinning of the mantle lithosphere $\beta \approx [8\text{-}10]$, the late syn-rift – early post-rift shallow mantle related alkaline volcanics, and the coeval occurrence of a second phase of extension in the internal basin part with the climax in compression in the external parts of the system around 12 Ma. The model predictions also suggest that the thickened crustal roots of the Apuseni Mts and the Trans-Danubian Range and related surface uplift may be interpreted in terms of rift flank uplift associated with extension of a weak lithosphere and lower crustal flow outwards of the rift zone.

PRE-ALPINE METAMORPHISM OF THE WESTERN CARPATHIANS: THE TATRIC UNIT

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Pre-Alpine metamorphic evolution of the Western Carpathians is best recorded in the Tatric unit where Alpine metamorphic overprint was generally only very low. The crystalline basement of the Tatric unit is exposed in several core mountains where metamorphic rocks are intruded by Variscan (350 Ma) granitoids. The metamorphic rocks show rather polymetamorphic evolution, with generally two distinct stages of metamorphism, differing in PT-conditions. .High-pressure metamorphism (M1) is preserved by relict in metabasites, indicating eclogite facies stage, i.e.: Plg-Cpx (diopside) symplectites after omphacite, kelyphitic rims of Plg+Amph around garnets, several generations of amphiboles etc. Although the peak pressure conditions cannot be evaluated, geothermobarometric calculations yield the PT conditions of 10-13 kbar and 650-700 ° C, recording the breakdown stage in the upper amphibolite to granutite facies conditions during the exhumations. Medium to low-pressure metamorphism (M2) is widespread, closely related to granitoid plutonism. High-grade metapelites and metabasites show intense migmati- tization due to partial melting. In metabasites, trondhjemitic to tonalitic leucosomes are developed by dehydratation melting of amphibole in the migmatitic (banded) amphibolites which contain sporadic lenses of retrograded eclogites. In metapelites, granitic to tonalitic leucosome was generated by dehydratation melting of muscovite and biotite in the sillimanite stability field (garnet and cordierite as a restite)

CONSTRUCTION OF THE STRUCTURAL CROSS-SECTIONS THROUGH THE CARPATHIAN FLYSCH BELT USING THE METHODS OF THE FREQUENCY ANALYSIS OF THE SEISMIC AND GRAVITY DATA

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The Flysch Belt area is on the contact of the Bohemian Massif and the West Carpathians. The data in this area include results from a number of deep boreholes (up over 6 km deep) and an extensive complex of geophysical measurements. The analysis of frequency charactericts of seismic and gravity data will bring the data about composition of density balanced cross-sections of the upper layer of the crust along selected seismic profiles and tracing of tectonic elements. The impact of the thrusting of the Alpine nappes on the deformation of the crystalline complexes and their sedimentary cover will be studied. Analysis of the frenquency od seismic and gravity data belongs to most recent geophysical research techniques. This technique makes it posible to identify from the seismic and gravity data rather low-amplitude structural-tectonic features. The method is based on combined analyses of the reflectance image of the derived gravity field and of the changes of the seismic echogenity.

GEOLOGICAL TRAVERSE R5 IN THE UKRAINIAN CARPATHIANS ACCORDING TO THE GEOPHYSICAL DATA

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The international geophysical travers II stretches across the territory of the Ukrainian Carpatheans. 6 more travers have been planned to explore. Among them 5 cross ones R1-R5 and one connecting P1. Travers R5 stretches from noth-east to south-west through Podilsko-Bukovinske uplands of the Easten European Platform, the Predcarpathian bending, Skiba zone and Crosno zone of the Central Carpathians. Along R5 seismic and gravimetric explorations are carried out, drillings to the depth of 6 kilometres are also made. Seismic studies are made using the method of general depth point. Reflected waves of good quality have been registered in the time interval to 6 seconds which corresponds to 12 km depth. Profile interpretation is fuifilled with the help of programme package SPS-PC(2D). Gravimetric studies are made 500x500 metres square, through wich R5 stretches. The interpretations is fulfilled with the help of "Density"(3D) package programmes. Detailed lethological- stratigraphical characteristics of the geological section and new data on tectonics are received. The given geologo-geophysical section is a basis for future perspective space geological studies and figuring out the true mechanism of the Carpathians genesis.

STRUCTURAL EVOLUTION OF ALPINE ECLOGITES: IMPLICATIONS FOR ALPINE GEODYNAMICS

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In the Eastern Alps Alpine eclogites are generally associated with rocks of continental lithosphere, while eclogites that are associated with oceanic assemblages are restricted to minor exposures. We investigated two areas within the Eastern Alps where eclogites and eclogite facies rocks which suffered a contasting P-T-d evolution are exposed: (1) In the central southern part of the Tauern Window (Eclogite Zone) eclogites and associated high pressure metasediments of a distal continental margin are intercalated between Penninic basement units. A mylonitic eclogitic foliation and stretching lineation are contemporaneous to the high pressure metamorphism and are related to the subduction of distal Penninic continental margin sequences. Omphacites show a well developed crystallographic preferred orientation. Continuous subduction of cool lithosphere resulted in blueschist facies overprint of the whole nappe pile. (2) Within the Middle-Austro-Alpine Koralm/Saualm region most eclogites are eclogitic mylonites documenting plastic deformation of omphacite with well developed CPO's, and plasticity of garnet. The structures indicate an overall extensional regime possibly related to a large-scale SE-directed ductile low-angle normal shear zone. The eclogites are associated with migmatite-like structures and are intruded by pegmatites. This indicates decreasing pressure, but isothermal or even increasing temperature conditions during exhumation. These relationships argue for the subduction of (Penninic) continental lithosphere in the foot-wall of the Austroalpine unit at the time of exhumation of the Koralm/Saualm eclogites. Formation of these eclogites is explained by subduction of cool continental lithosphere, and subsequent, rapid exhumation in a lower plate tectonic position within an extensional regime.

TECTONIC AND RHEOLOGIC EVOLUTION OF SEDIMENTARY BASINS IN THE PANNONIAN-CARPATHIAN AREA

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The peculiar geophysical and geodynamic situation of the Neogene PANCARDI system is a result of the complex interaction of tectonics and lithosphere rheology in the area. Analyses of tectonic subsidence in several sub-basins of the Pannonian basin system s.l. indicates the existence of at least two different periods of rapid subsidence which are interpreted as individual extension phases. Karpatian extension is evident in all sub-basins as the initial phase of rapid subsidence. In some sub-basins (Vienna and East Slovakian basin) this phase is manifested as a transtensional one. In other sub-basins Karpatian extension took place by a simple-shear mechanism (Danube basin, Styrian basin). In the central parts of the Pannonian basin system, a second phase of rapid tectonic subsidence is interpreted for Sarmatian - Early Pannonian times. This phase is also observed in the peripheral basins of the Pannonian basin system as a minor subsidence increase. A marked contrast between peripheral and central basins also exists in the evolution of lithospheric strength. The peripheral basins are charcterised by a general strengthening after Karpatian times. The Central basins portray a distinct weakening of lithosphere rheology. These changes in lithospheric rigidity have pronounced effects on the stratigraphic evolution of the sedimentary basin overlying the Pannonian lithosphere.

JOINT TOMOGRAPHY INVERSION OF THE CARPATHIAN ARC IN ROMANIA

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Two sets of traveltime data were combined for the calculation of a joint inversion after Roecker. The current teleseismic data set for this regional study of the Vrancea Region was recorded between 1991 and 1997 from the National Romanian Seismic Network and contains 120 teleseismic earthquakes with P and PKP first breaks. In addition we used about 5000 P and S arrivals from local events that were already inverted by Oncescu for his PhD-thesis.
The major feature of the inversion results is a high velocity volume that is continous with increasing depth. The extension in the upper part between 20km and 120km is from northeast to southwest. In the lower part below 120km the high velocity volume is limited to the seismic active volume. Between 35 and 70km it is separated into two parts divided by a volume with lower velocities. This range fits with the seismic inactive region as far as the crust-mantle boundary. The strong influence of the Moho topography under the Carpathian Foredeep (Focsani Basin) is demonstrated by variations in the model parameterization. The resolution capability of the inversion method is evaluated with a synthetic calculation. It shows the sensitivity of the method with regard to velocity perturbation value variations within the slab structure. This must be suggested especially in context of Moho undulations.

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PALEOMAGNETIC RESULTS FROM TERTIARY PODHALLE FLYSCH, POLISH WEST CARPATHIANS

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The Podhalle basin is part of the Inner Carpathian flysch basin system, situated between the Tatra Mts. and the Pienniny Klippen Belt.
Of the 30 Paleogene localities, inspected in the basin, eventually 10 localities were sampled for the present paleomagnetic study, which also included low field susceptibility anisotropy measurements.
The magnetic fabric of the sampled beds may be described as dominantly foliated (degree of foliation is 4-9 per cent). Lineation is subordinate (0.4-1.2 per cent). Maximum susceptibility directions either cluster or are intermixed with the intermediere directions in the plane of foliation. When they do cluster, they are roughly E-W directed, in agreement with the general sedimentary transport direction in the flysch basin.
The remanence is often overprinted. Nevertheless, characteristic remanences of moderate stability may be identified at most localities. For the successful ones the measured declinations are westerly, inclinations are somewhat shallower than the present inclination, suggesting that the tectonic transport was accompanied by moderate northward shift and large counterclockwise rotations.

MECHANICS AND RHEOLOGY OF THE EARTH'S CRUST OF THE TRANSCARPATHIANS ACCORDING TO SPATIAL-TEMPORAL STRUCTURE OF SEISMOGEOACOUSTIC MODE AND A COMPLEX OF GEOPHYSICAL DATA.

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Ukrainian Transcarpathians is a seismically active region characterised by tectonic compression perpendicular to the Carpathians, small (25 km) thickness of the Earth's crust, higt (upto 130 mw/sq.m) heat flow, crust earthquakes of average intensity and small (upto 12 km) depth of hypocenters. Specific character of a seismic mode and peculiarities of local earthquake mechanism are due to strong differentiation between rheological properties of rocks and the depth, and are expressed by the following parameters: spatial-temporal migration of earthquakes with specific temporal and spatial features and distinctive mechanisms, tectonic localization of hypocenters, characteristics of microseismic fields, correspondent spatial-temporal variations of seismic, acoustic and nonlinear-parametric charactericties of rock massifs, as well as strain variations, variations of magnetic and electromagnetic fields, changes of electric resistance of rocks.

RECONSTRUCTION OF THE GEODYNAMIC DEVELOPMENT OF THE NORTHERN CALCAREOUS ALPS BASED ON PALEOMAGNETISM — REVIEW AND NEW DATA

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Major problems regarding the structural development of the Northern Calcareous Alps (NKA) include their position relative to the southern and northern continental margins of the Tethys during the Jurassic/Cretaceous and the details of a possible lateral extrusion of the Transdanubian Range during the Cretaceous caused by the indentation of the NKA by the Southern Alps. Within the last two decades, valuable paleomagnetic data were obtained from various units of the NKA, however, apparently contrasting results led to alternative geodynamic interpretations, mostly owing to an insufficient temporal and spacial density of sampling. As a part of a new ongoing study we review the paleomagnetic data set obtained until now and also present new data from several sections of the upper Cretaceous (Gosau) strata in Austria: Sites from the Inntal region (Tyrol) typically yielded both easterly and westerly magnetization components depending on the depositional facies type, likely due to clockwise rotation and subsequent acquisition of a diagenetic magnetization component. However only cw rotations were obtained from the Gosau in the vicinity of Salzburg and only ccw rotations from sites in the Neue Welt in the vicinity of the Vienna Basin. These data support a geodynamic model involving sinistral displacement of the NKA east of the Bohemian massif.

STRUCTURE AND CONTENTS OF THE WEST CARPATHIAN ACCRETIONARY WEDGE: INSIGHTS FROM BALANCING AND SAND-BOX MODELING

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The restoration of structures along five balanced cross sections through the West Carpathian accretionary wedge and pseudo-3D restoration in the Smilno Tectonic Window area shows that various defined units are parts of Magura and Silesian Basin fills. The shortened Magura Basin fill was detached at the Upper Cretaceous stratigraphic level. The shortened Silesian Basin was detached at the Lower Cretaceous stratigraphic level. The Magura Basin was the western neighbor of the Silesian Basin. Both basins were shortened during Paleogene; the Magura Basin due to collision and the Silesian Basin due to subduction. The Magura Unit thrust over the Silesian Basin fill as the out-of-sequence oblique thrust during the Neogene. The general shortening mode is piggy-back. Thrust geometries are created by both fault-bend and fault-propagation folding. The frequent out-of-sequence thrusting is caused by the involvement of the basement in the shortening and by the friction/erosion interplay. Interpreted structures are compared with sand-box models. Variations in friction along the basal thrust include the low friction, documented by subhorizontal veins with vertically grown fibers and long thrust sheets, medium friction, indicated by duplexing and high friction, indicated by antiformal stacks and back thrusting.

PLATE TECTONICS OF THE APULIA-CARPHATIAN REGIONS

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We propose a new plate model for the development of the Carpathian arc in which a major role is played by the movement of the Apulian plate between Africa and Europe. The successive developments and closures of the Meliata and Vardar oceans and the subsequent subduction of the Alpine Tethys are reponsible for the development of the Pannonian basin as well as the Carpathian - Dinarides mountain belts. Many of the terranes now compressed into the Carpathian arc were formerly distributed along the passive margins of the Meliata and thereafter the Vardar ocean. Subduction of the Meliata ocean leads first to the back-arc development of the Vardar ocean and the eventually to the subduction of the Austroalpine s.l. terranes and the Alpine Tethys. The subsequent closure of the Vardar ocean induces the displacement of the Apulian plate towards the NE. This produces an eastward lateral escape of the northern most terranes of the Apulian plate at the transition to the Austroalpine s.l. plate (Transdanubian range, Bükk, Apusini/E-Tizia, Mesek/W-Tizia), which are delivered. The Apulian promontory subsequently moves to the W, to finally collide with the passive margin of Europe. The traction exerted by the subduction on the Alpine Tethys in the paleo-Carpathian region, pulls the terranes into their final position.
Reference : http://www-sst.unil.ch

EXHUMATION OF THE TAUERN WINDOW, EASTERN ALPS

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The exhumation of metamorphic domes within orogenic belts, as exemplified by the Tauern window in the Eastern Alps, is often related to partitioning of final shortening into deep-seated thrusts, near-surface antiformal bending forming brachyanticlines, and almost orogen-parallel strike-slip faults due to oblique continental plate collision. Low-angle normal faults at releasing steps of crustal-scale strike-slip faults accomodate tectonic unloading of synchronously thickened crust and extension along strike of the orogen, forming pull-apart metamorphic domes. Initiation of low-angle normal faults is largely controlled by rock rheology at the brittle-ductile transitional level within the lithosphere. Therefore, several mechanisms may contribute to uplift and exhumation of previously buried crust within such settings: (1) shortening along deep-seated blind thrusts resulted in formation of brachyanticlines and bending of metamorphic isogrades; (2) oversteps of strike-slip faults within the wrench zone control the final geometry of the window; and (3) unloading by tectonic unroofing and surface erosion. Rapid decompression of previously buried crust results in nearly isothermal exhumation paths, and enhanced fluid circulation along subvertical tension gashes (hydrothermal ore and silicate veins) that formed due to overall stretching of lower plate crust. In contrast, the upper plate

FAST CLOCKWISE ROTATION IN THE EASTERN PANCARDI REGION DURING MIDLE MIOCENE

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Recent K-Ar ages show that the Miocene volcanism in the Apuseni Mountains took place between 14.7 - 7.4 Ma. Several sites sampled for both K-Ar ages and paleomagnetic measurements. The new paleomagnetic data are grouping in two distinct clusters: one characterized by about 550and the other by 220 clockwise rotation with respect to Europe. The mean age of the first group is around 14.2 Ma and for the second one is 13.0 Ma. Previous paleomagnetic sites, probably younger than 11-12 Ma, reveal no rotation. Recent paleomagnetic results from Eocene rocks from Transylvanian Basin show that the entire basin was rotated around 670 post Eocene. The new paleomagnetic results indicate that most of this clockwise rotation took place very fast during Late Badenian - Early Sarmatian. These data point that the rotation of the eastern part of the PANCARDI region took place after the cessation of the counterclockwise rotation of the northern part of the PANCARDI area. According to available paleomagnetic data the movements are sudden and, long time elapse without discernible change in the orientation of the paleomagnetic vectors. Similar characteristics of the paleomagnetic data were also observed in other areas of the PANCARDI region.

KINEMATICS AND METAMORPHISM OF A CRETACEOUS CORE COMPLEX: THE VEPORIC UNIT OF THE WESTERN CARPATHIANS

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The Veporicum is the middle of three south-dipping thick-skinned basement/cover imbricates of the Central Western Carpathians. These originated by Cretaceous crustal stacking of the lower plate due to collision after locking of the Meliatic ocean. The exposed eastern part of the Veporic superunit in Central Slovakia shows a domal structure with onion-like arrangement of Variscan basement and Permomesozoic cover complexes. The Alpine metamorphic overprint reaches ca 600°C and 11 kbar in the deepest exposed basement unit (micaschists) and ca 450°C and 6 kbar in metasediments along the southern periphery of the dome. Thermochronological, preferably Ar/Ar data indicate cooling and exhumation starting at ca 110 Ma (amphiboles). to 90-80 Ma (micas). The core complex was exhumed by a generally east-dipping low-angle normal fault accompanied by a huge ductile shear zone with top-to-east shear sense indicators. The metamorphic isograds are telescoped and sometimes discontinuous within this extensional shear zone embracing topmost Veporic basement and all cover complexes. The unroofed overburden involved basement/cover units of the overridden Gemeric sheet and a higher stack of the Meliatic accretionary-suture complexes.

MORB BASALTS FROM MELIATA - HALLSTATT OCEAN (MELIATA UNIT, INNER WESTERN CARAPATHIANS)

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In Gemericum Mesozoic basalts occur in the Meliata group (Mock 1980) in three subunits that are close to each other as for age and their geotectonic pattern: 1/ *Jaklovce group* and 2/ *Meliata group s.s,* 3/ *Bôrka nappe.* In the former there are mostly basalts (rarely pillow lavas) and gabbroes closely associating with serpentinites and radiolarites. The basalts often penetrate through radiolarite schists that belong to the Middle through Upper Triassic. They have preserved relicts of a primary association of Cpx and Plg. As for composition Cpx are augites (Morimoto et al. 1988), and/or they correspond to those from tholeiitic rocks (Leterrier et al. 1982). With reference to different discrimination diagrams (Pearce and Cann 1973, Pearce and Norry 1979, Meschede 1982, Floyd and Winchester 1975, Mullen 1983, etc.) and REE distribution pattern they correspond to N-type MORB. The basalts of Meliata group s.s. have been altered to a high degree and have not preserved primary minerals, geochemically they are like those of the Jaklovce group. Along with basalts there often occur lizardite-chrysotile serpentinites, radiolarites, lydites and others. Bôrka nappe contain basic rocks experienced metamorphism HP/LT condition. Volcanic activity culminated in the Carnian and Norian. The occurrence of MORB-type basalts together with the presence of ultrabasites and radiolarites prove that the Meliata-Hallstatt had an ocean-type crust as early as the Upper Triassic.

MULTILAYER P-WAVEFORM INVERSION MODELS OF THE EARTH'S CRUST IN THE EAST CARPATHIAN REGION

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Our previous P-waveform inversion study resulted in 5-6 gross layer models of the Earth's crust beneath the three broadband stations of East Carpathian Regional Seismic Network. P- and S-wave velocities and quality factors as well as layer thicknesses were determined as statistically independent model parameters. Initial models originated from deep seismic sounding data. Then, we repeated the inversion analysis for the same stations using 25-30 layer P-wave velocity models with constant P- and S-wave quality factors and layer thicknesses. Densities and S-wave velocities were substituted by P-wave velocity expressions. In the first experiment, deep seismic sounding models were randomized to create the families of initial models with prescribed P-wave velocity variation range. In the second one, the gross layer inversion models were used to produce the sets of initial models. Sets of final models appeared to split forming the several groups with different models as the centers of attraction. These models are analyzed and compared to taking into account their resolution and how they fit the observables.

STRUCTURAL DEVELOPMENT OF INNER PART OF THE MAGURA NAPPE, OUTER CARPATHIANS (POLAND)

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This paper discusses structural evolution of the inner part of the Magura nappe which is the innermost nappe of the Outer Carpathian fold-and-thrust-belt in Poland. The study of small-scale structures has been combined with analysis of: map-scale features, mineral veins and clay minerals. Five groups of small-scale structures have been analysed: deformation bands, clastic dykes, hydroplastic faults, joints and brittle faults. The structures of particular groups have been dated in relation to: (i) the structures of other groups, (ii) map-scale features, (iii) appearance of particular types of mineralization, (iv) increasing induration of the strata involved and, (v) diagenetic maturity. In result, we have traced structural history since deposition of the strata involved, through their lithification up to their complete induration. This history comprises two successive periods. The first period comprised folding and thrusting which started in the Paleocene time, during deposition of the strata involved, and was completed during Eocene times when these strata were still poorly indurated. The second period occurred when the involved strata were completely indurated. This period comprised several successive stages of strike-slip and normal faulting. The bulk of mineralization occurred during the second period.

MICROFABRICS AND CPO'S AT DIFFERENT STRUCTURAL LEVELS OF THE EASTERN CENTRAL ALPS: IMPLICATION FOR THE RHEOLOGICAL EVOLUTION OF A COLLISIONAL OROGEN

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The Eastern Alps are generally subdivided into two mega-units: (1) the Austroalpine nappe complex, and the (2) Penninic nappe complex (exposed within the Tauern Window), that are separated by the ophiolithic suture of the Glockner Nappe. Both mega-units include a pre-Alpine basement covered by Permian to Mesozoic, and partly Cenozoic cover sequences. Both mega-units are characterized by polyphase deformations at different metamorphic and rheological conditions. During distinct phases of Alpine orogenesis these units have been incorporated within several Austroalpine and Penninic nappes. Nappe stacking within the Austroalpine unit ocurred during the Lower Cretaceous. Within foot-wall units (Middle-Austroalpine basement) the microfabrics and CPO's indicate deformation at elevated temperatures and pressures (amphibolite facies metamorphic conditions). In contrast, in the hanging-wall (Upper Austroalpine basement) deformation during nappe stacking occured at greenschist facies metamorphic conditions. Nappe stacking within the Penninc unit ocurred during the Upper Cretaceous/Lower Tertiary at eclogite to blueschist facies metamorphic conditions, and is contemporaneous to underplating beneath the Austroalpine nappe assemblage. This triggered the formation of large-scale SE-directed ductile low-angle normal shear zones and subsequent (semi)brittle faults in the upper plate (Austroalpine nappe stack). During the final lateral extrusion (Tertiary) ductile deformation was concentrated along the rheological weak rocks (meta-carbonates) of the former suture (Glockner Nappe).

Meliata , Hronic and Fatric orogenies of the West Carpathians Revealed by deep reflection seismics in the East Slovakia

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Eighty kilometres long deep seismic line G through the East Slovakia passes the East Alpine – West Carpathian Mesozoic orogenic collage in its easternmost part where all participating tectonic units are condensed and relatively undisturbed by later Cenozoic tectonic processes. The innermost fragment of the Late Jurassic Meliata orogeny is formed by only three kilometres thick wedge broadening southwards and cut by the Darno Cenozoic strike-slip fault in the South. Meliata wedge was eroded from below by a Gemer thrust sheet. This is formed by imbrications of Paleozoic rocks slices above the suture of Hronic nappes which was formed during and after Hauterivian. Hronic nappes root in subhorizontal mid-crustal decollements. Seismically most important whole crustal package of strong reflections is caused by a South dipping thrust faults of Fatric and probably as well South Penninic origin. Meliata and Gemeric – Hronic nappes formed the upper plate for the Fatric – South Penninic orogeny. Both, Hronic and Fatric orogens were southwesserly verging, but the sense of the Meliata orogeny is not clear. The opposite vergency is as well possible.

SIGNIFICANCE OF GOSAU BASINS FOR THE UPPER CRETACEOUS GEODYNAMIC HISTORY OF THE ALPINE-CARPATHIAN BELT

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Important information on the lithospheric response to orogenic processes can be extracted from the sedimentological record of sedimentary basins, and their structural relationship to the adjacent basement. The formation of Upper Cretaceous "Gosau" basins, all over the Alpine-Carpathian area, is a key feature for that time and represents the connecting link between surface and subsurface processes.The characteristic features of Gosau basins are: (1) Gosau transgression follows crustal thickening events by thick-skinned nappe imbrication. (2) A combination of strike-slip and normal faults plays an important role during basin formation. (2) The commonly two step subsidence history with a moderate initial subsidence followed by a distinct subsidence pulse, causing a major facies change from alluvial and shallow water to a deep marine depositional environment. Isotopic studies clearly show, that major vertical movements of previously metamorphosed basement series within the orogenic system are contemporaneous with basin subsidence. As a consequence lithospheric strenght is reduced in these thermally active regions and subsequent collapse of the mechanically weak crust, which can not support large stresses provides a plaussible trigger for Gosau basin formation in internal positions of the orogen.

INTEGRATED LITHOSPHERIC MODELLING IN THE WESTERN CARPATHIANS

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Although the Western Carpathians belong to the regions which are geophysically well surveyed, the study of its lithosphere structure has usually been performed by independent interpretation of the single geophysical fields. We present now a two-dimensional numerical model using combined interpretation of heat flow density, absolute topographic elevation and the gravity data. The applied FE algorithm connects temperatures and densities through the thermal expansion coefficient and calculates topography under the assumption of local isostatic equilibrium. The crustal structure is known from seismic data whereas the thickness of the thermal lithosphere is obtained by trial and error. The method was applied to a transect that extends from the European platform, via the Western Carpathians to the Pannonian Basin and intersects in NNW – SSE direction all geological units of the Western Carpathians. The results of the integrated modelling indicate remanents of a lithospheric slab underneath the Carpathians. While the Central Western Carpathians are characterized by a lithospheric root (the deepest part is observed under the Pieniny Klippen belt) the Moho is relatively flat and normal depth. The mean lithospheric thicknesses vary from about 100 km under the European platform through 140 km underneath the Carpathians to about 80 km under the Pannonian Basin.

3D-FLEXURAL MODELLING OF THE WEST- AND EAST CARPATHIAN TRANSITION ZONE: PROBLEM DESCRIPTION AND PRELIMINARY RESULTS

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We analyse the 3D-flexural expression of the obliquely interacting subducting/underthrusting processes acting on the West- and East-European lithosphere. We concentrate on the lateral variation in effective elastic thickness (eet) of the lithosphere. The weak zones, control the main flexural bending of the lithosphere and the stronger zones, are able to transfer the flexural intra-plate stresses.
Large bending stresses under the East- Carpathian mountain belt cause dramatic yielding of the subducting /underthrusting lithosphere. As a consequence of the loss of lithospheric strength fexural stresses can no longer be transmitted to the foreland of the East- European lithosphere, but are possibly transferred laterally affecting the subsiding Polish foredeep.
However, in order to explain the folded shape of the foredeep in S.E. Poland, "passive" interaction is not sufficient: we suggest possible NW continuation of the East-Carpathian system under the foredeep in S.E. Poland. A dynamic explanation for this interaction may be sought in the space problems that occur because of subducting/underthrusting convergent European lithospheric plate boundaries. that, therefore, may even overlap (?).

NEOTECTONIC STRUCTURES IN THE OUTER EAST CARPATHIANS, POLAND, IN THE LIGHT OF MORPHOMETRIC STUDIES

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The Outer East Carpathians represent a typical fold-and-thrust belt which is composed of a stack of nappes, piled one upon another throughout the Middle-Late Miocene. Numerous pieces of evidence, provided, i.a. by well-bore breakouts, deformation of oil industry well logs, structural data and geomorphic studies, all indicate Late Cenozoic tectonic activity of this area. Classical geomorphic studies, focusing on deformations of planation surfaces and fluvial terraces, make it possible to distinguish a number of elevations and depressions that are orientated WNW-ESE in the southern and NW-SE in the northern parts of the Outer East Carpathians of Poland. These structures are also detectable on maps of relief energy, envelopping surfaces, as well as on isobase maps. Small widths of these structures and their subparallel arrangement in respect to the strike of principal thrusts and folds allow one to suppose that they originated due to Pliocene-Quaternary relaxation of remnant horizontal movements within the flysch nappes (Late Cenozoic folding?). Similar conclusions can be drawn from analyses of time-series of river-bed gradients and of some river valley parametres, including the valley width/valley height ratios, that show zones of abnormally high gradients being associated with nappe fronts, without any appreciable lithological control. The zones of abnomally high river bed gradients, decreased widths of valley bottoms and of clearly increased relief energy tend to be confined to the axes of NW-SE trending elevations.

NEW DATA ON STRUCTURAL HISTORY OF SILESIAN AND MAGURA NAPPES, OUTER CARPATHIANS (POLAND) INFERRED FROM ANALYSIS OF CROSS-FOLD JOINTS

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Cross-fold joints have been studied at 250 stations located within the Silesian and Magura nappes along the 320 km long Polish segment of the Outer Carpathians. These joints comprise one or two systems, each of them composed of a single set of T joints and two conjugated sets of D1 and D2 joints. In both nappes cross-fold joints of all sets are symmetrically arranged within the map-scale folds. Both T joints and the acute bisector between the D1 and D2 joints strike subperpendicular to the map-scale fold axes. This indicates interrelation between the cross-fold joints and the map-scale folds and the relationship of cross-fold joints to far-field stresses. Analysis of cross-fold joints revealed the following aspects of structural history of the nappes discussed: (1) in both nappes, strata underwent compresional stress regime since Paleocene up to Early Miocene times; (2) during the same period, the stress field orientation remained constant in these nappes, with possible exception of western portion of the Magura nappe and; (3) both nappes were folded only once with the exception of a portion of the Magura nappe which was folded twice.

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INDUCED SEISMICITY IN THE NETHERLANDS

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In 1986 the Northern part of the Netherlands started to show seismic activity due to the exploitation of gas fields. At that moment only one seismic station was present in the region. The monitoring of the seismicity, which is a basic task of the KNMI, improved considerably with the installation of a network of 11 borehole seismometers in 1995. Until the end of 1997 a total of 160 events were recorded at a depth of 1-3 km and magnitudes between -1 and 3.4. The very shallow depths of the events cause high intensities at low magnitudes and in 1996 it was decided to install accelerometers at locations that experienced multiple events. During 1996 and 1997 acceleration data are collected from a series of 8 events near the town of Roswinkel. The magnitudes of these events are between 1.3 and 3.4. The recorded peak horizontal accelerations for the largest event amounts to 0.3g at a dominant frequency of 10 Hz. This last event caused damage to buildings in the region. Results will be shown of a magnitude calibration within the region, determinations of relative locations and source parameters of events around Roswinkel.

A NEW DIRECT INVERSION OF EARTHQUAKE FOCAL MECHANISMS TO RECONSTRUCT THE STRESS TENSOR

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The reduced stress tensor includes the orientations of the three principal stress axes σ_1, σ_2, σ_3 and the ratio of principal stress differences, $\Phi=(\sigma_2-\sigma_3)/(\sigma_1-\sigma_3)$. For an homogeneous subset of double couple mechanisms, this tensor can be determined through inversion of data, under the classical assumptions of mechanical consistency. This is a classical problem for geologists in brittle tectonics.
In the case of focal mechanisms, however, there is an additional problem, that of the choice between nodal planes of double couple focal mechanisms. Classically, the answer either consists of avoiding the choice by using the right dihedra (P- and T-dihedra) method, or aims at performing this choice in various ways prior to numerical inversion of data (see an example in Iceland, Angelier *et al.*, this meeting).
It is demonstrated that there is a third possibility, which allows one to carry out the mathematical inversion of data and to obtain the complete reduced stress tensor, without doing any choice between the nodal planes of each earthquake.
Furthermore, the formulation is such that it is possible to carry out the inversion by pure analytical means, based on cancelling partial derivatives relative to the unknowns of the reduced stress tensor. The solution of the problem is thus straightforward and numerical problems are avoided.
Using a simple direct inversion of double-couple mechanisms of earthquakes enables one to focus on a more important problem, that of the inhomogeneity of data sets in terms of stress states. Separation into subsets is made easier because in the new method calculation is extremely brief despite the complexity of algebraic derivations.

OBSERVATORIES AND RESEARCH FACILITIES FOR EUROPEAN SEISMOLOGY (ORFEUS)

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ORFEUS is a European non-profit organisation that aims at coordinating and promoting digital, broad-band seismology in the European-Mediterranean (EuroMed)area. Its services are presently mainly available through the internet, although we pursue an active support of e-mail data access (autodrm@knmi.nl). The Orfeus Data Center (ODC) provides broad-band waveform data consisting mainly of regional (EuroMed) quality controlled data (1988-1993) available on CD-ROM (presently 20) or on-line, and global SPYDER^R data (1993-present/near real time) which is on-line (web, ftp and AutoDRM) available.
ORFEUS maintains also services, which aim at facilitating waveform data access and exploiting this data. These services include an inventory of permanent broad-band stations, mobile seismological equipment and relevant projects, and an overview of waveform data access in the EuroMed region. A technical support group provides practical information, support and news on seismological sensors and recording equipment. The ODC regularly support participants with technical assistance on dataconversion and response characterisation.
Additional services include the ORFEUS Seismological Software Library (SSL) containing links to and mirrors of (generally freely available) relevant seismological and related software. Seismo-links complements Steve Malone's seismosurf with adresses to organisations, geophysical datasets, publications, earthquake information, e-mails, etc. especially within the EuroMed region.

MONITORING ELASTIC-WAVE VELOCITY VARIATIONS IN THE EARTH'S CRUST USING MACHINE NOISE

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We present the use of narrowband machine-noise signals for the purpose of monitoring elastic propagation velocities in the crust. Such continuously generated signals are measured at a large number of seismological stations around the world. An ideal test case is given by the short-period GERESS array in Southern Germany (Bavaria). There we consistently observe a signal at 2.083 Hz on the 25 vertical instruments. Phase differences obtained from station pairs are related to changes in the propagation velocity. For long time windows, such phase differences show daily variations with a spectral content closely corresponding to the predicted solid Earth tide. We interpret this correlation as an effect of varying gravitational load on propagation velocities through the crust. The main mechanism for such changes is preferential opening and closing of cracks and fissures. Results are related to previous observations of temporal velocity changes observed in a deep borehole at depths between 4 and 9 km. That depth range is particularly important and interesting since most of the large crustal earthquakes are initiated in that depth range.
If crustal velocities are sensitive to changes in the mechanical stress field, we may indirectly observe the buildup of tectonic stress within the crust.

RINALIG EXPERIMENT ON T WAVE MEASUREMENT IN LIGURIAN SEA

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2 legs addressed an active seismic investigation of Ultra Low Frequency acoustic wave interactions with continental slope. The survey was carried out off the Antibes and Menton coasts in the Ligurian basin, Mediterranean. 5 short period inland seismometers were settled along a short, 2km long line normal to the sea front, and 4 OBS (3D short period seismometers associated to 1 hydrophone) were laid by pairs at 2 and 20km from the coast line on the continental slope (at 400m depth) and on the sea floor (at 2200m depth). Air gun shots were processed at 7m depth seawards and at 15m depth landwards in the *Sofar* channel from the coast up to 80km off the shore. These shots were recorded in the 2-50 Hz frequency band. Besides the different Pn and Sn branches, no T wave was observed on the ashore seismometers for the Menton leg while a strong T wave was recorded for the Antibes leg. This phase mainly consists of 3 superimposed Rayleigh waves which were separated by signal processing. They show 3 polarizations that correspond to three frequency domains with a constant phase (*vs* frequency and source offset) of the intercorrelation between horizontal and vertical components. The shallow depth of the source suggests that the acoustic field trapped in the *Sofar* may be compared to a set of thin beams that sweep the coastal slope. Thus, the conversion of the *Sofar* acoustic field to inland elastic field which defines the T wave detection ability of the site studied depends on the coupling rate of the sweeped areas. This rate can be accurately characterized by such an experiment that make use of sources with offsets from coast line lower than 80km.

ITERATIVE METHODS IN RAY SEISMIC TOMOGRAPHY

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Principal problems for any ray seismic tomography modification are an angle coverage incompleteness and non-linearity. The angle coverage incompleteness causes the nonuniqueness of the solution (for the case when the slowness variation occupies the all ray-covered zone) and computational instability for the solution of a linear equation system. Using a non-linear tomography iteration procedure permits to eliminate this dependence, but the problem of a high computer complexity remains. Study of kernel of the ray-transformation in rectangular zones (it is the situation which takes place in the tele-seismic, cross-well and reflection tomographies) allows us to specify the uniquely determined parameters. The problem of computational instability due to the angle coverage incompleteness is being still unsolved. It is known that for the case of full data the slowness variations are estimated stable, therewith there are the explicit conversion formulas. The effectiveness of the iteration algorithm, where the explicit inversed formula of full data is applied for the every step, is demonstrated. The real features of the observation system are taken into account for the forward problem solution (the similar operator method). The results of comparative study for different methods of nonlinear tomography : the Gauss-Newton method, the Newton method, the modified Newton method and similar operator method are covered in this work.

EXACT EARTH-FLATTENING PROCEDURE FOR P-SV OR RAYLEIGH-TYPE VIBRATIONS

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The technique which permits to compute synthetic seismograms for a spherically symmetric medium using methods initially designed for a flat layered medium has been studied in seismology for about three decades. It is called the Earth flattening procedure. The first success in flattening had been achieved in the early Seventies for SH or Love-type vibrations by Gerver and Kazhdan in the USSR, and by Biswas and Knopoff in the USA. All attempts to find a similar flattening procedure for the more complicated P-SV vibrations have failed. We found a solution to this problem as a byproduct of a theory developed for the inversion of P-SV vibrations. Using an idea of C. Pekeris dating back to 1934, we transformed the equations for Rayleigh-type vibrations of flat, spherically and cylindrically layered media into a Sturm-Liouville form. The media can then be subdivided into sets, or orbits. Any two media belonging to the same set can be linearly transformed one into another. Media with different symmetries -flat and spherically layered, for example- can belong to the same orbit. In this case, the flat model is the result of flattening the spherical model. The most important distinctions between the P-SV and SH flattening procedures are: 1) the flattening for P-SV waves is frequency dependent, and 2) it is valid over intervals with smoothly varying parameters of the medium.

THE STON–SLANO (CROATIA) EARTHQUAKE SEQUENCE OF 1996

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The Ston–Slano earthquake sequence (main shock 5 September, 1996, $M_L = 6.0$, I_{max} = VIII °MSK) is the largest seismic series in the greater Dubrovnik area since the catastrophic earthquake (I_{max} = X °MCS) of 1667. The earthquake completely destroyed three villages, and caused heavy damage in a number of southern Dalmatian cities. The peak near-field ground acceleration recorded in Ston was as high as 0.65 g. The main shock was followed by thousands of aftershocks, of which 1350 could have been reliably located. The aftershock epicentres fall into a well defined elongated ellipse with a major axis directed NE–SW, and over 100 km long, which is remarkable for an event of this size. The *a posteriori* analysis of seismicity pattern in a larger area of Southern External Dinarides (using the CN algorithm) revealed significant seismicity anomalies (TIP) one year prior to this earthquake. The microseismic data (arrival times of various local and regional phases) will be used to assess the velocities of seismic waves within the seismogenic volume, whereas geologic data, hypocentral locations, and fault-plane solutions are used to identify main geotectonic features of this seismic source zone.

GEOLOGICALLY CONSISTENT TOMOGRAPHIC SUBSURFACE STRUCTURE DETERMINATION FROM SEISMIC DATA

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A tomographic workflow for 2D subsurface structure determination is presented. The tomography uses as input migrated prestack gathers from reflection seismic data. The workflow is designed especially for Geologically complex areas. The first stage of the procedure is to obtain an interpretable image of the subsurface. Starting from a simple interval velocity section. prestack variable offset depth migration is carried out. The migrated variable offset gathers are used for updating the velocity section by grid tomography. Typically this process is repeated four to five times until a reasonable subsurface image is obtained. However very often the resulting velocities do not follow the structure and do not make any geological sense. The next stage of the process is the interpretation of the seismic image and the extraction of a subsurface depth-velocity model. The formation velocities of the model are derived from the velocity section used for the migration. The extraction is also done tomographically in order to ensure that the seismic zero offset travel times will not be changed. The final stage of the workflow is a model based tomographic update of formation thicknesses and velocities.

AMPLITUDE WEIGHTING OF THE FRESNEL VOLUMES OF P-WAVES IN THE EARTH GLOBAL MODEL.

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P waves play an important role in the recent global tomographic studies of the Earth mantle. Corresponding Fresnel volumes give a suitable tool for estimation of the resolution limits or accuracy of the tomographic methods. This approach is based on kinematic data only (arrival times) of the seismic waves which penetrate the Earth mantle. Standard definition of the Fresnel volume is based strictly on kinematic variables only. This mean that no dynamical parameters (e.g. amplitudes or geometrical spreading) are used. Due to this definition we have no possibility to estimate the contribution of individual part of the Frenel volume to the final wave field in the receiver. As opposite to this, main scope of our contribution is to estimate the distribution of the amplitude weighting function in the crossection plane located along the Fresnel volume central ray. This weighting function can contribute to the evaluation how different parts of the Fresnel volume can influence the recorded wave field. The weights are defined on the base of knowledge of the amplitudes along the virtual rays corresponding to the Fresnel volume. Through the whole computation the zero order ray method has been used. We limited ourselves to the computation for 1-D global Earth model only. First preliminary results are presented.

UPPER CRUST ANISOTROPY IN ICELAND

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The three component seismic records from 65 local crustal earthquakes (depth is up to 20 km) at 10 seismic stations located in south-west part of Iceland are investigated. Time of observation was 2 months (July - August, 1991). The direction of horizontal component of the first shear wave (HCFSW) and time delay between two shear wave were determined. It was shown that the HCFSW has approximately the same direction (0-15deg from north to east) for all seismic stations. The time delay can achieve up to 0.03 sec/km. The investigated dependencies of time delay between two shear waves reduced to hypocentral distance from effective source depth allows us to estimate the velocity structure of crust of studied area. It is possible to make a conclusion about existence of anisotropic layer in the Earth crust on the depth 3 - 4.8 km with rather strong coefficient of anisotropy (~ 20%).

THE ACOUSTIC AND ELECTROMAGNETIC PHENOMENA IN THE ATMOSPHERE DURING THE VIBROSEISMIC SOUNDING

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It has been known that the acoustic and electromagnetic effects show themself during the earthquakes and explosions. The powerful seismovibrators with 100 tons force amplitude are mounted at the "Bistrovka" testing area of Siberian Branch of RAS (Novosibirsk). They work both in the sweep-regime and in the monochromatic regime and permit to generate the seismic oscillations with the given frequency-time characteristics. The apparatus contains the magnetic induced sensor (with the sensitivity about 0.001 nT), the sensor of atmospheric electric field (sensor of the string type with the sensitivity about 0.001 Pa) and the control seismometer. This apparatus has permitted us to investigate the electromagnetic and acoustic phenomena arising during the work of seismovibrators in the frequency range from 5 to 10 Hz on the distances: 100-700 m, 5-6 km and about 50 km. We have established in our experiment the existence of the electromagnetic wave radiated on the vibrator frequency and propagating with the light velocity. This phenomenon can be conditioned by the excitement of the currents (on the vibrator frequency) in the atmosphere and lithosphere by the action of the acoustic and seismic waves. It was shown that this effect did not connect with the controlling electric chains of the mechanical instruments as this effect observed also during work of the hydroresonance vibrator with pneumatic drive. In the points with the distance from vibrator about several kilometers the synchronous (with time) the acoustic and seismic modes are observed.

THE DENSITY MODEL OF THE SEICMIC FOCUS ZONE OF THE SUUSAMYR EARTHQUAKE

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In this study, we are considering the peculiarities of the density sections of the seismic focus zone of the Suusamyr earthquake (19.08.1992, M=7.3,H=25 km) which had happened in the western part of the Central Tien-Shan . This seismic event has a long aftershock process which is continued at present. The seismic focus zone confined by aftershocks has the sizes: 80 km long, 15 km width and 25 km depth. It is within a block limited both sublatitude major faults - Suyekh and Suusa- myr-Issykkul and north-western minor faults. According to a neotectonics scheme the blocks move from west to east inside the area limited sublatitude maior faults. Under these conditions it is an actual problem to reveal the inverse low density layers which promote both the realization of the subhorizontal displacements and the relative autonomous movement of the layers during deformation events. The densities have been calculated by the empiric formula. Initial data are the P- and S-wave velocities from the 3-D velocity tomography model of the Tien-Shan (Roecker et al.,1993). Analysis of the density sections has show that west of the Suusamyr earthquake focus zone the upper part of the earth crust (to 20 km) consists of the high density rocks (2.88-2.95 g/cm3) lieing on the low density layer (2.65 g/cm3). It provides the subhorizontal displacement of the upper layer. However east of the focus zone the other type of the density section has been observed.There is an uplift of the dens mantle rocks into both the middle and upper crust here. Owing to that an accumulation of strains which were released during Suusamyr earthquake occur. The seismic focus zone fills in the low density part of the earth crust (H=5-25 km) and is wraped by the high density rocks. The hypocenters both the major event (M=7.3) and the most powerful aftershock (M=6.7) are on bottom of the low density layer. Because of the major sublatitude faults limit the seismic focus zone their basement has apparently 20-25 km depth.

COMPARISON OF LINEAR AND NON-LINEAR EARTHQUAKE LOCATIONS FOR THE 1995 VENTIMIGLIA SEQUENCE

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The ML=4.7 1995 Ventimiglia event (French-Italian border) caused some damage and was widely felt. Because this sequence occurred near a coastline, with few stations to the south, there is large north-south uncertainty in the event locations. For notification of civil authorities and for later seismicity and hazard studies, it is important to have both accurate event locations and comprehensive uncertainty estimates. Also, because of structural complexity in tectonic regions, it may be useful to use location procedures valid for 3D structures.
We obtain probabilistic re-locations for the Ventimiglia sequence using a grid-search approach for 3D media. For this algorithm, we calculate once and store the traveltimes between each station of the network and all nodes of an XYZ spatial grid, using an Eikonal finite-difference scheme (Podvin and Lecomte, 1991). Next, for each event we apply successively finer grid-searches over XYZ space to obtain an estimate of the probability density function (PDF) for hypocenter location, following the approach of Tarantola and Valette (1982).
For the Ventimiglia sequence, we present and compare the event locations and uncertainty estimates obtained with the non-linear, grid-search approach (the PDF's) to the those (uncertainty ellipses and hypocenter) produced by Hypoellipse, an iterative, linear algorithm (Lahr, 1989).

AN ACCURATE THREE-COMPONENT OBSERVATION OF ELASTIC WAVEFORM BY USING A LASER DOPPLER VIBROMETER: A NEW METHOD OF PHYSICAL MODELING TO STUDY SEISMIC WAVES IN COMPLEX MEDIA

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We applied Laser Doppler Vibrometory (LDV) to laboratory physical model experiments for studying seismic wave propagation. LDV eliminates mechanical and electrical couplings between vibration sensor and object, because it directly converts the vibrational velocity of a material's surface to the Doppler shift frequency of the laser. The laser beam can be focussed on a very narrow area, less than 0.4 mm in diameter. This enables detection of fine changes in the elastic wave field. Measurements of three-component waveforms in the ultrasonic wave range has been achieved by detecting motions of small spherical lenses (60 μm dia.) embedded in a reflection sheet, which reflects laser beam right in the incident direction. LDV can, therefore, simulate realistic field seismic observations in laboratory experiments. We measured three components of elastic waves propagating through rocks with different grain sizes, which were used as models of inhomogeneous materials with different scales of inhomogeneity. The waveforms suggest that elastic waves are mostly scattered as S waves, and the scattering becomes strong when the characteristic size of inhomogeneity is comparable to the wavelength.

A PC-based program using a Multi-Algorithm Approach to Automatic Detection and Location of local earthquakes

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A few automated data acquisition and processing systems are operated on mainframes, some are run on UNIX-based workstations and some on PC equipped with either DOS or UNIX-derived Operating Systems. We present a new PC-based software package to automated earthquake monitoring, named ASDP_Seism, which using a visual object-oriented interface and a multi-algorithm approach to the on-line detection and location of local earthquakes. Its operative mode is similar to that used in more complex systems, where the algorithms run on different processors and a parallel computations is generally performed. The automated procedure is enabled for 1- and 3-component, stand-alone or networked data gathers. In order to optimize the efficiency of a seismic monitoring system, the software is provided with full detection capability and makes use of a high degree of automation, aimed to minimize the analyst workload. Related extensive tests of ASDP-Seism were carried out on events and seismic sequences recorded both in tectonic (Calabria) and volcanic areas (Mt.Etna, Aeolian Islands, Mt. Vesuvius, Afar Rift). Testing results are obtained both in simulated on-line processing and using a dataset of recorded earthquakes.

INVESTIGATION OF THE CRUSTAL STRUCTURE IN SOUTH-EAST GERMANY USING RECEIVER FUNCTIONS

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Receiver functions are used to investigate the crustal structure in the region of the Saxothuringian–Moldanubian suture zone in southeast Germany. This suture zone is well visible in reflection seismic data as SE dipping ramp–structure. Across the structure the fast polarization axis as documented by SKS data expiriences a significant change in direction. The data were recorded by a mobile teleseismic network of 24 broadband stations spreading about 200 km in north–south direction and crossing the suture zone perpendicular in the middle of the profile. Data processing comprised restitution, rotation, deconvolution and moveout corrections. The most prominent features in the data are the P-SV conversions from the Moho and its free surface multiples. Free surface multiples reflected from crustal discontinuities indicate a south dipping structure extending from the middle of the profile to the south. Location and extension of this structure coincide with the Moldanubicum–Saxothuringicum suture zone obtained from DEKORP data. Inversion results provide high upper crustal velocities and a low velocity zone in the southern and a relatively smooth crustal structure in the northern part of the profile. Our study indicates that significant structural features of continental crust can be determined from receiver function data, which are confirmed by high resolution reflection seismic data.

SE21

PROVIDING SINGLE STATION PHASE DATA TO A SEISMIC WARNING SYSTEM

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A high accuracy phase picker is implemented at the Dutch seismic broad-band station HGN to make accessible in quasi real-time P-phase onset times. The procedure can be initiated through an AutoDRM request. The seismic alert system at the European-Mediterranean Seismological Center (EMSC) uses this mechanism to extract P-phase picks from HGN, which are used in obtaing accurate event locations. The current picker implementation seems robust for high (above 10) signal to noise ratio onsets.
We are investigating the usage of the automatic picks in a practical implementation to fully exploit the potential relevant information in 3-component recordings, to provide additional information to the EMSC like azimuth, polarity and phase identification.
Also, we investigated confidence intervals for the automatic picks and compared these with differences between automatic and manual picks for all data in 1996.

FLUID PRESSURE AND SEISMIC REFLECTIVITY IN THE LOWER CRUST

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Seismic reflection profiling of the continents has shown that lower crust is in general significantly more reflective than upper crust. Several sources of the origin of lower crustal reflectivity have been suggested including compositional layering related to ductile flow, igneous intrusions, and zones with fluids. We consider the problem whether pore fluids liberated from the rocks during metamorphic reactions can produce near-lithostatic pressure in the lower crust. Such pressures may induce a decrease in seismic velocity large enough to produce seismic reflectivity. Calculations of fluid production and movement in a heated lower crust have been carried out using the Darcy law for a viscous matrix. Such calculations show that pore pressure may be near lithostatic within the layer of devolitilization. If fluids are liberated from the lower crustal rocks during the thermal evolution of a specific area, they may locally be a source of seismic reflectivity.

SE22 Images of the continental lithosphere by active seismic methods

Convener: Rabbel, W.
Co-Conveners: Gallart Muset, J.; Thybo, H.

ACTIVE VIBROSEISMIC METHODS IN MODERN SEISMOLOGY PROBLEMS

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A new method for seismological investigation of the Earth's crust and the upper mantle, geodynamic processes and earthquake preparation zones has been developed using powerful vibrational sources of seismic waves. Since nuclear explosions have been prohibited, this method remains the only active method for deep seismic sounding of the Earth. Advances in the experimental research with powerful vibrators make it possible to consider the active seismology method as a new tool for studying the Earth, whose technology is similar to seismic prospecting methods. The paper considers an information system for data collection and data processing for active vibroseismic monitoring of seismic-prone zones, studies of the Earth's structure and geodynamics, and mathematical problems of geophysics connected with active seismology.

P- and S-wave Velocity Structure of the San Andreas Fault System in the San Francisco Bay Area

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As part of a new 3-D, crustal-scale seismic velocity model being compiled for the San Francisco Bay Area, we focus on understanding the seismic structure of the deep crust. We use seismic P- and S-wave data from earthquake recordings and seismic refraction surveys to determine the variability of physical properties (i.e. P- and S-wave velocities, Poisson's ratios and the deep crustal lithology) across the San Andreas Fault, the Hayward Fault and other faults in the San Francisco Bay Area. Common receiver seismograms show very clear P-wave (Pg) phases as first arrivals out to offsets of 70-85 km, as well as the direct shear wave (Sg) phase as secondary arrivals. The N-S striking P-wave velocity model of Holbrook et al. (1996) in the Bay Area Block has been used as an initial model to derive the S-wave structure assuming a crustal Poisson's ratio of 0.25. Our preliminary model differs with respect to crustal thickness and Moho topography in the southern part of the Bay Area. We find 1) Low upper crustal S-wave velocities in the south Bay Area (Vs ~ 2.8-2.9 km/s compared to 3.0-3.12 km/s in the north); 2) High Poisson's ratios of 0.29-0.33 in the upper crust in the south Bay Area; 3) South-ward thickening of the middle crustal layer with lower P-wave velocities (~6.7-6.8 km/s); 4) South-ward dipping Moho from 24-32 km of depth over a horizontal distance of ~60 km; and 5) Lower upper mantle P-wave velocities (~7.8 km/s). Based on these preliminary findings we prefer interpreting the lower crust beneath the southern San Francisco Bay Area as a remnant of an altered oceanic crustal layer (i.e. the subducted Pacific/Farallon oceanic crust?).

3-D PRESTACK MIGRATION OF THE ISO89-3D DATA SET

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In 1989 a 3-D seismic reflection survey was carried out as part of the program *Integrated Seismics Oberpfalz* (ISO89) in the vicinity of the German continental deep drill hole (KTB) in the Oberpfalz area, Germany. 3327 Vibroseis 'shots', each with 478 receivers and a maximum recording time of 7 s, covered an area of approximately 21x21 km^2 centered around the KTB. This paper presents the results of a 3-D prestack Kirchhoff migration of this data set.
For each shot a migrated volume was generated by weighted integration along diffraction surfaces through the shot record. The diffraction surfaces were computed with the help of a finite difference eikonal solver. A macro velocity model obtained mainly from wide angle measurements served as input. The slices through the final migrated section, obtained by stacking of the individual migrated volumes, clearly show the position and the lateral extent of several strong reflectors. Over nearly the whole survey area a northeast dipping paleo shear zone can be identified from its outcrop at the surface down to a depth of approximately 8-9 km with a maximum dip angle of about 55 degrees. Its shape and reflection strength changes laterally as well as with depth. At 9-10 km depth a highly reflective zone appears in the southeastern part. The slices reveal its complicated structure and show its dip towards the center of the survey area reaching a depth of about 10-11 km directly beneath the KTB.

INVESTIGATION ON SHALLOW FAULTS BY SEISMIC T* VALUES

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We have developed a technique to measure seismic t* value. Utilizing small earthquakes, spectral decay method is performed to calculate t* values. The empirical approach eliminates common source, propagation, instrument and near-surface site effects. According to the empirical relationship between the rise time and the t*, the rise times for each earthquake propagating to each station can be deduced. The technique was applied to 57 events with epicentral distance < 60 km and focal depth < 50 km and propagating through a fault area of northern Taiwan. The distribution pattern of t* values shows a trend of relatively high value near the surface trace of two exists faults in Taiwan.

CRUSTAL STRUCTURE OF THE NORTHERN TYRRHENIAN FROM REFLECTION-REFRACTION DATA

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In the frame of the LISA cruise, between the corsica and tuscan margins some seismic stations were deployed on land in order to obtain wide angle seismic reflections up to the crust/mantle boundary. The integrated interpretation of vertical and wide angle seismic reflection data shows some prominent features of the crustal structure of the northern Tyrrhenian basin :

- this basin is divided into two different areas by the Elba ridge. On the eastern side of the ridge a young (Pliocene) extensional tectonics is evident. On the western side an old (Oligocene?) and huge basin is adjacent to the Corsica margin.The Elba ridge itself is characterized by young intrusions and older compressional features The intrusions upturn the sedimentary layers and the compressional features are indicated by westwards dipping reflectors seen on the LISA profiles up to 7 sec. TWTT.
- clear intracrustal reflections are evidenced from both near vertical and wide angle phases. outlining the deformation history of the basin from an earlier compressive stage to the subsequent tectonic phase characterized by extension related to the opening of the tyrrhenian sea-a good reflector at 7-8 TWT marks the crust/mantle boundary. which in thetuscan side is interpreted at 20-22 km depth. The Moho is much deeper (11 TWT. about 30 km) on the Corsica side.

Deep structure of the North Tyrrhenian Basin from on land seismic recording and Multi-Channel Seismic profiles.

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Combined onshore wide-angle reflection/refraction and offshore multichannel seismic profiles have been acquired during the LISA seismic cruise that surveyed the Ligurian and the Tyrrhenian sea in 1995. The ray-tracing modeling of wide-angle and refraction seismic data shows, in the northern Tyrrhenian sea, the Corsica basin at 9km deep and the moho at a depth of 30km under Corsica island. Towards the Tuscany margin, however, the moho rises up to 15km under the Montecristo ridge. As well as that, we can see on onland seismic data a prominent reflective late arrival, associated to the asthenosphere, at a depth of 50km under Corsica to 35km under the Tuscany margin. These lithospheric seismic reflections fit with the results of a tomographic study of N.Bethoux and with deep penetration seismic profile Crop3 in Italy. Beneath the Corsica margin and Montecristo ridge, some deep reflections can be observed between 10 and 12 secondes. These deep reflections may correspond to the moho of the Corsica island (30km deep). Additonally, the M.C.S line shows a prominent reflection at 8 secondes TWTT correlated to the Tuscan moho at 15km deep according to the refraction data. In conclusion, we think that there is no European moho beneath the Tuscany moho; but lithosphere reflections. Our data confirm the rise of the moho in the northern Tyrrhenian sea, associated with the crustal rifting.

LITHOSPHERIC INVESTIGATION IN THE SOUTH EASTERN NORTH SEA

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In the MONA LISA project (Marine and Onshore North Sea Acquisition of Lithosheric Seismic Analysis), 4 lines of seismic reflection data were collected in the south-eastern North Sea. Wide angle data were recorded by 34 OBH (Ocean Bottom Hydrophones) and onshore stations at 3 of the lines.
Wide angle p-wave velocity models show resolve different velocities of the crystalline basement, probably delimited by the border zone between the ancient Avalonia and Baltica continents. The velocities vary between 5.5-5.7 km/s in Avalonia and 5.9-6.2 km/s in Baltica crust. The Moho depth is strongly decreased underneath the Central Graben, but no crustal thinning is visible underneath the Horn Graben. General differences in crustal thickness seem to be connected with recent tectonic features rather than with the origin of the continental terranes. Traces of a collisional front are hard to identify. Some south respectively west dipping reflections in the normal incidence data, which cut the top Pre-Zechstein reflector may be in Permian extention reactivated Caledonian deformation faults. Close to the crossing point of line 1 and 3 a strong reflection is observed at 21 s TWT. Three wide angle stations from both profiles show similar features at near offset. The reflector was modelled to a depth of 70-72 km. It may be interpreted as the top of a subducted slab.

Deep structure of the Ligurian sea along a Nice-Calvi line from on land seismic recording, Multi-Channel Seismic profiles and Expanded Spread Profiles.

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Single bubble guns were used during the LISA seismic cruise that surveyed the Western Mediterranean Sea. One seismic profile between Nice and Calvi, was shot along 4 E.S.P previously recorded in this area. The shot were also recorded on the Corsica margin, in order to constrain better the structure of the continental margin. The seismic profiles shows the deep basin where the Messinian salt diapirs and the multiple do not allow a good penetration. Nevertheless the acoustic basement is evidenced at about 6 sec TWTT (two-way travel time), on the M.C.S line and on the refraction data (ESP and onland recording). The moho arrival is complitely hide by the multiple on the M.C.S line in the basin, owing to the refraction data we can proposed an image of the moho. On the land recording the arrival associted to the moho is very clear, and the ray tracing modeling give us a moho at 30km deep under Corsica margin rising to 15km under the Ligurian basin. On the Corsican margin, the acoustic basement rises and several reflectors can be seen beneath this basement. These reflectors dip toward the margin and the deepest one is visible from 6 sec TWTT in the Northwest to 9 sec TWTT. Beneath the narrow shelf of Corsica several deep reflectors can be seen between 9 and 10 sec TWTT. The 10 sec TWTT deep reflector corresponds probably to the Moho according with refraction recording. Despite the disturbance and complexity brought by salt tectonics. the simultaneous study of the multichannel seismic profiles, expanded spread profile and land recording allow to propose a well constrained crustal model and a velocity model of this area.

DEEP STRUCTURES OF THE MENORCA MARGIN FROM DEEP SEISMIC SURVEY

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The Menorca margin is well known by the seismic survey of the DSDP Site 372 (Leg 42). The northern and eastern margins show a steep slope characterized by echelon-like horst and graben structures disposed towards their base, while the southeastern margin shows also a steep slope but no evidence of extensional features, probably explained by a major transfer fault that separates it from the eastern margin. The deep multichannel LISA cruise surveyed these two margins: Between Menorca and Sardinia, the basement is quite flat with an internal reflection at 7 sec TWTT. The paleozoic basement probably outcrops between the island untill 40 Km offshore. From 45 and 35 km, several deep reflections dip from 7 to 10.8 seconds towards Menorca; on the northeastern margin the slope is more progressive but the horst and grabens are not evident because the profile available crosses a high between two grabens. Between 20 km and 50 km from the island the basement is covered by a thin sedimentary cover (0.6-08 sec TWTT) that thickens basinwards (1.8 sec TWTT) after a prominent step from where a thin salt layer appears. Beneath the continental shelf several deep reflectors (6-8 sec TWTT) observed may represent a lower layered crust. From 50 Km a prominent reflective horizon (7,8 sec TWTT) dips to 10 sec TWTT towards the island. A first comparison with wide angle data suggests that the deep reflectors on both margins are situated at the top of a high velocity layer (7 km/s) and can be compared with the reflector T identified in the Gulf of Lion.

PRESERVATION AND ORIGIN OF PALEOZOIC COLLISIONAL FABRICS IN THE SOUTHERN URALS - URSEIS '95

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The crustal scale seismic image of the Southern Uralide orogen from the vibroseis CMP-reflection profiling component of the URSEIS '95 experiment shows a preserved doubly vergent belt with a significant crustal root, as the result of two major partly superimposed collisional events: (1) the development of a Devonian W-facing accretionary complex and (2) a Permian collision with the eastward accretion of the Transuralian terranes. While the E-vergent accretionary prism involves the entire crust with the Moho as the basal detachment, the thick-skinned W-vergent structures only include the upper part of the crust, suggesting different rheologies of the plate fragments and collisional processes. The rather low thermal influence across the entire Urals emphasizes that the compositional features of the involved crustal units take the main role: mafic to intermediate rocks dominate in the accreted Siberian island arc and oceanic collage, while the former passive margin of the East European craton is probably controlled by a quartz-feldspar rheology. The present day reflectivity pattern has also to be interpreted as the sum of several orogenic imprints. The orogenic root zone as defined by wide-angle data is poorly imaged in the vibroseis near vertical reflection data. Gravity and petrophysical modelling suggest that the crustal root is composed of mafic eclogitic rocks which inhibits Moho reflectivity. In contrast to other Paleozoic mountain belts, which suffered substantial tectonic denudation and postorogenic crustal thinning, the Urals evolved near isostasy and never departed far from equilibrium and preserved its collisional seismic patterns.

THE WESTERN ENDING OF THE PYRENEES: CRUSTAL STRUCTURE OF THE BASQUE-CANTABRIAN BASIN

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The crustal structure of the western prolongation of the Pyrenees along the Basque-Cantabrian basin has been investigated in a seismic refraction experiment carried out in summer 1997. In the survey, up to 100 3-component portable stations recorded 9 land shots of 1500 kg explosives each. Main targets were: the eastern extension of the crustal root recently evidenced beneath the Cantabrian Mountains area were the variscan crust has been intensively reworked by alpine deformation, the geometry of the crustal thickening and the similarity with the Pyrenean structure, and the relationship between the Cantabrian-Pyrenean chain and the northern Celtiberian chain. The P and S velocity-depth functions will enhance the geophysical constraints on the northern margin of Iberia, being an asset for understanding the interaction between Iberian and European plates, and for geodynamic modelling of an active margin, from the tectonic inversion of former extensional basins up to the subduction and continental collision. First results of the survey show lateral variations in crustal structure, with a gradual thickening toward the central part of the Pyrenees, and strong variations of more than 10 km in crustal thicknesses in the Basque Massifs area, which may delineate a present complex geometry between Iberian and European crusts resulting from the important extension occurred in the Basque-Cantabrian basin prior to Pyrenean collision.

CONTINENTAL CRUST IN THE MENORCA MARGIN: VELOCITY-DEPTH CONSTRAINTS

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During the LISA deep seismic experiment on the Western Mediterranean, the multichannel profiles along the ESE and NNE margins of Menorca were also recorded at far offsets by two portable stations operating in the island. The continental nature of the crust is documented by the velocity-depth modelling of these data. The upper crust is characterized by a 6.0 km/s seismic basement at 3 km depth, and a velocity increase to 6.4 km/s is found at about 13 km depth. A remarkable feature, not detected in other Balearic wide-angle surveys, is the presence beneath the E flank of Menorca of a 5-7 km thick lower crust of velocity around 7.2 km/s, constrained by amplitude fitting of the reflectivity observed at its top and bottom. The Moho is marked by a clear PmP reflection, and the crustal thickness of the E part of Menorca is around 27 km, thicker than reported before. The interpretation of the NNE profile indicates a Moho shallowing of about 3 km towards the north. Comparison of the multichannel sections and the wide-angle models in terms of TWTT shows a good agreement on the deep crustal structure documented seawards by both methods.

LOCAL TOMOGRAPHIC STUDY OF SOUTHERN FINLAND

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Seismic tomography method is applied to quarry and DSS shot data to estimate the P- and S-velocity anomalies. Also the anomalies of Poisson ratio are obtained. An a priori model was derived as an average crust-upper mantle model from DSS results. In the inversion block sizes of *50 km × 50 km × layer width* are used. The results show similar behaviour for both P- and S-wave velocities. A comparison with the interpretation of SVEKA profile agrees with these observations. At a depth of about *77 km* the anomalies change from negative to positive under the NE Moho depression. The velocity anomalies indicate also the border zone between the Archaean and Svecofennian domains.

The results are restricted by several simplifications in modelling and inversion. To improve the tomographic image the number of events should be increased by regional earthquake data, and a more sophisticated method should be used for ray tracing.

TOMOGRAPHIC RECONSTRUCTION OF THE VELOCITY DISTRIBUTION IN THE NORTH-WEST PART OF KOLA PENINSULA. IS IT POSSIBLE?

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The main goal of the computer simulation performed was the estimation of advantages and disadvantages of tomographic method as a tool for the reconstruction of 3D seismic-geological model of the north-west part of Kola peninsula on the basement of seismic data accumulated within 1958-1997 years. Tomographic approach was applied for the simulated experimental data which could be obtained from the analysis and selection of archive seismic materials and the creation of unified data base from the separate seismic investigations which had a place in the north-west part of Kola peninsula within 1958-1997 years. A lot of reports and papers were reviewed in order to create the imagination what the above mentioned unified data base could be. As a result, several thousands pairs of source/stations were used for the data simulation. The estimation procedure was based on well known sensitivity test. 2/3D kinematic modelings and several approaches of tomographic inversions were performed with seismic tomographic package FIRSTOMO. Observation scheme and quality of the reconstruction are shown from different points of view.

LOWER CRUSTAL REFLECTIVITY AT THE BOUNDARY BETWEEN THE TRANSSCANDINAVIAN IGNEOUS BELT AND THE SVECOFENNIAN DOMAIN

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Using reflection seismic data, we have studied lower crustal reflectivity in relation to the boundary between two Proterozoic terranes in Sweden: the Transscandinavian Igneous Belt (TIB) and the Svecofennian Domain (SD). Previous work on data from the Siljan Area, Central Sweden, indicated that the lower crust was less reflective below the TIB than below the SD. In order to test if this is a general pattern connected with this boundary, running in north-south direction through Central and Southern Sweden, we have processed data from the eastern segment (~50 km long) of the 1992 Vibroseis profile in Jämtland, acquired ~250 km north of the Siljan Area. The profile runs from SD crystalline rocks, to the east, across the Caledonian thrust front onto the Phanerozoic sedimentary cover, in the western part believed to overlie TIB rocks. Down to 3 s TWTT (~9 km depth) the data reveal high reflectivity, tentatively attributed to extensive dolerite intrusions within a large antiform. The deep apparent reflectivity (10-15 s), generally low, is higher on the eastern part of the profile, indicating the same pattern for the TIB/SD boundary as in the Siljan Area, although lateral variation in signal penetration must be studied. At 15 s (corresponding to ~50 km depth), there is a decrease in coherent energy, possibly related to the Moho. We will compare the Jämtland data with data from BABEL Line B, believed to cross the TIB/SD boundary in the Baltic Sea.

CRUSTAL STRUCTURE OF THE BOTHNIAN SEA

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The Bothnian Sea is located on the Fennoscandian Shield between Southern Finland and Central Sweden. The Bothnian Sea is characterised by regional Bouguer minima (between -45 and -75 mGal) in the north, maxima (between -20 and +14) in the middle parts and minima (between -40 and - 60 mGal) in the southern parts. According to combined interpretations of the BABEL reflection and refraction data and gravity data, the northern part Bothnian Sea comprises of rapakivi granites related to the Nordingrå and Bonden rapakivi granites. On BABEL lines 1 and 6 the rapakivi granites and related gabbros appear as non-reflective laccoliths in the upper crust. In the north-eastern-most part, the granite is overlain by a 3-4 km deep Jotnian sedimentary basin that causes both velocity minimum and Bouguer anomaly minimum. The Bouguer anomaly maximum in the central parts is associated with unreflective intrusive structure in the middle and lower crust. This is interpreted as dioritic central intrusion. The intrusion is surrounded by linear Bouguer minima, that in reflection data are imaged as shear zones dipping away from the intrusion. The southern Bouguer minimum is associated with the Åland rapakivi granite, that is non-reflective and includes bright reflections mimicing graben and horst structure. Both in the southern and nothern parts the crust is characterized by dipping reflectors and highly reflective lower crust that are interpreted to image sub-Jotnian and post-Jotnian extension of the area.

DEEP STRUCTURE FROM DSS DATA AND TECTONIC SETTING OF SOUTHERN APENNINES

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Some aspects of the geometry and kinematics of the Southern Apennines are still poorly understood. In the recent years different authors proposed conflicting models of the deep tectonic setting of this fold and thrust belt on the base of different emphasis given to seismic data or to tectonic observation on outcrops. In order to add more deeper constraints to perform a forward modelling of the tectonic structures on regional balanced cross sections in this area, seismic refraction data carried out in the seventies and eighties have been reprocessed and interpreted. The obtained models show the adriatic plate subdutting quite regularly below the so called "tirrhenian" lithosferic domain, with the crustal tickness increasing from 15 km in the basin side to 30 km under the appenninic chain.

THE LITHOSPHERE TOMOGRAPHY USING SUPER POWERFUL VIBRATIONAL SOURCES

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Further development of active seismology methods and, in particular, of the Earth's global tomography is connected with creation of new instrumental research systems, which use super-powerful vibrational sources of seismic waves and disrtibuted systems of recording and processing of geophysical information. The paper considers the experience in vibroseismic research of Earth's crust and upper mantle with the powerful vibrators and specialized field seismic arrays, which have been carried out in the Siberian Branch of RAS (Russia) during the last 20 years. A project of the network of super-powerful vibrational sources with a force of 10000 tons and a frequency range of 0.5–5 Hz for the purposes of the global seismology is presented. Seismic waves are excited by the water column with the weight of about ten thousand tons, which oscillates in the vertical shaft. Such sources can be constructed in military rocket shafts, which are not used now due to reduction of arms.

LITHOSPHERIC STRUCTURE ACROSS THE IAPETUS SUTURE ZONE IN IRELAND: TELESEISMIC OBSERVATIONS ALONG A CONTROLLED SOURCE PROFILE.

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The Caledonian Iapetus suture is a tectonic boundary resulting from the amalgamation in a three-plate configuration of Laurentia and Baltica with Avalonia. In SW Ireland, a wide-angle seismic profile crossing the postulated path of the Iapetus suture recorded some reflections from the upper mantle. These can be explained by an interface in the mantle which shallows from 44 km to 39 km just south of the Shannon River. Along this same profile a set of teleseismic events was recorded as well. The P-wave residual times for an earthquake in the Aleutians, end-on to the line, and a nuclear test in China, nearly orthogonal to the line, show large variations, of about 0.5 second, along this relatively short profile. Heterogeneities in the crustal structure along this line can account for very little of the variation in residual times and most of it must originate in heterogeneities below the crust. The residual times are explained by a velocity contrast of about 3%, across a steeply dipping interface from the Moho down to 110 km, located just south of the Shannon River. Both results are consistent with previous work which located the Iapetus Suture Zone south of the Shannon River. The steeply dipping interface from the teleseismic observations indicates that the closure of the Iapetus Ocean may have involved a southward subducting slab.

THE WIDE-ANGLE MOHO ACROSS THE SOUTHERN URALS

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The geometry of the Moho beneath the Urals has been a controversial issue since the first geophysical studies of this orogen. The lack of a root is supported by a moderate -50 mGal Bouguer minima along its axis. Seismic data acquired during the last decade suggest an increase in crustal thickness beneath the orogen (up to 65 km) and the existence of a high velocity lower crustal layer (7.6-7.8 km/s). Although seismics seem to constrain the location and shape of the crust mantle boundary, none of the published data sets provide a well resolved image of the Moho. The normal incidence URSEIS-95 seismic data produced a high resolution image of the internal architecture of the orogen. The Moho appears as a sharp interface at the West and Eastern edges of the section. However, the Moho is not imaged beneath the Magnitogorsk volcanic arc. An NMO correction without stretch was used to stack the the seismic wide-angle component of the URSEIS-95 after a narrow band pass filter (1-6 Hz). This procedure generates a significantly well resolved imaged of the crust-mantle boundary. Beneath the core of the orogen the crustal thickness increases from 43-46 at the edges up to 50-55 km. The changes in the character of the PmP suggests posible variations in the origin and nature of the Moho. from an old cratonic Moho beneath the European Plate; to delaminated and orogenic Mohos beneath the Magnitogorsk zone and Siberian plate, respectively.

THE ORIGIN OF THE BAIKAL RIFT: HYPOTHESES AND SEISMIC DATA

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The origin of the Baikal rift has been explained either as a result of thermal excitation of the underlying mantle or as a passive response to lithospheric extension. To decide between the two alternatives, the rift and its surroundings were scanned till a depth of 250 km by 40 portable digital seismographs along a 1000 km profile traversing the rift in the SE direction from the Siberian Platform to Mongolia, and by two broad-band stations of permanent run. The rift zone showed to stand out against the Siberian Platform and Mongolia by shapes of Ps converted waves, generated in the crust-mantle transition layer, as well as by lower P-wave velocities in the lithospheric mantle beneath the rift, yielded by inversion of crust and uppermost mantle receiver functions and teleseismic tomography. At the same time, 1.7 to 2.0 ratios of P- and S-wave travel-time anomalies are typical rather of compositional variations than partial melting, and the thickness of the phase transition zone, temperature-sensitive at depths from 400 to 650 km, is close to the normal one. Therefore, no unambiguous explanation for the rift origin can be so far obtained, and further studies by a denser network of broad-band seismographs are needed.
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The LITHOPROBE Western Superior Transect: a close look at the Archean Lithosphere

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The two major unresolved questions regarding the Archean eon are whether or not plate tectonics was active during the Archean, and whether the Archean lithosphere has a bulk composition that is fundamentally different from lithosphere of other ages. Insights to these questions are provided by seismic refraction data from the LITHOPROBE Western Superior Transect (WST) which is located within the western part of the Superior Province in northwestern Ontario, Canada. The Superior Province is the largest and best exposed Archean crustal block in the world and forms the nucleus of the North American continent. The internal structure of the Superior Province records a history of the processes that formed some of the earliest lithospheric elements of the Earth into cratons, thus providing an ideal laboratory for investigating early lithospheric evolution.

Data from the WST include high-resolution seismic refraction/wide-angle reflection profiles recorded along two long range (660 km aperture) transects oriented parallel and perpendicular to tectonic strike. We have studied the 3-D geometry of granite-greenstone and metasedimentary belts patterns and their relation to the underlying sub-crustal lithosphere. Since both P- and S-wave arrivals are recorded, we have constrained the composition of the Archean lithosphere through the study of Vp/Vs ratios.

VARIATION IN DEPTH AND CHARACTER OF THE 400 KM DISCONTINUITY

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The top of the transition zone (the 400 km discontinuity) is usually considered as a sharp boundary at a relatively constant depth. However, interpretation of PNE seismic sections from Eurasia indicates that there exist at least two interfaces with variation in depth and reflection character; in a few sections the 410 km reflection is even masked by the coda from the shallower reflection. Hence, there is indication that the 400 km discontinuity is not always sharp and that there is a transition zone in the depth interval from 370-420 km depth in some parts of Eurasia. The reflection pattern between the 370-km and the 410-km reflections appears analogous to the pattern observed in crustal record sections for reflections from the lower crust and Moho, apart from the obvious differences in frequency content, offset and traveltime. Kinematic modelling indicates that the depth range between the two reflectors is variable, of 30 to 60 km thickness, and that it is characterised by relatively low velocities.

SHEAR WAVE ANISOTROPY OF LAMINATED LOWER CRUST: SEISMIC FIELD DATA COMPARED WITH LABORATORY DATA

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In order to investigate the laminated lower crust beneath Urach (SW Germany), we analyse (1) the anisotropy and reflectivity of seismic shear waves and (2) the composition of xenoliths samples. We conclude that the directional dependence of shear waves of the lower crust is effectively transversely isotropic with a maximum velocity difference of 3 to 6%. Both seismic signature and petrological information are compared with reference profiles deduced from the exposed lower crustal sections of Ivrea and Calabria (Italy). The comparison, based on synthetic seismograms, shows that the observed combination of shear wave anisotropy and reflectivity pattern corresponds to alternating layers containing a high amount of metapelites, such as found in the Calabria profile and in the Val Strona subsection of Ivrea. The layers have to be intrinsically anisotropic. A pure "layering anisotropy" caused by rock sequences of individually isotropic layers is too weak to explain the observed shear wave splitting. Layered mafic intrusions, such as found in the Val Sesia subsection of Ivrea, do not seem to play a major role for the laminated lower crust at Urach.

URSEIS'95 - NEW RESULTS AFTER THOROUGH REPROCESSING OF THE EXPLOSION-SOURCE REFLECTION-PROFILING COMPONENT

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Project URSEIS'95 is an integrated multi-seismic experiment carried out by scientists from Russia, Germany, USA, and Spain to provide insight into (1) the internal structure of the Ural orogen, (2) the geometry and nature of its crustal root and Moho boundary, and (3) the mantle structure and reflectivity beneath the orogen. The near-vertical incidence explosion-source reflection component of the survey reveals an unique lithosphere-scale seismic image of the southern Urals (*Knapp et al., SCIENCE 274/1996*). A detailed inspection of the dataset leads to the conclusion, that its intrinsic richness of geoscientific information is so high that conventional seismic processing-sequences will probably not exhibit its entire potential. Thus, a thorough reprocessing of the 500 km long explosion profile consisted of a careful review of the field geometry and a plausibility cross-check with the seismic data, a mainly single-shot based preprocessing with special emphasis on manual editing of the several noise effects, a true-amplitude conservation as far as possible, a spatial variation of all processing parameters with strict inclusion of geological knowledge, a correct handling of dipping structures using τp-methods, and finally an application of modern depth-migration techniques. Now, in addition to the already known Alexandrovka (25 s TWT) and Nikolaevka (45 s TWT) Reflection Sequences several other super-deep mantle events (down to 55 s TWT) can be traced as well as some Moho reflectivity in the crustal root zone (18 s TWT). As a whole, the reprocessing of the explosion-source profile provides a clearer seismic image of the deep structures, which (in combination with the coincident vibroseis- and refraction survey) can lead to a more complete interpretation of the Uralides' lithospheric architecture and of the genesis and behaviour of continental crust in collisional belts.

THE TRANSITION FROM "COLD" TO "HOT" AREAS OF NORTH AMERICA AND THE LOCATION OF HIGH SEISMICITY ZONES

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The western part of the North american continent is characterised by low average seismic velocity in the upper- most mantle and high heat flow and the central to eastern part by high average uppermost mantle velocity and low heat flow. However, the details of the transition in the mantle between these two characteristic areas remain unknown. The long-range seismic sections of the Early Rise experiment identify a characteristic delay of refractions from below the Lehmann discontinuity on most profiles. The delay coincides with a transition from continuous, homogeneous first arrivals to seismic phases, which are scattered in travel time and amplitude, similar to arrivals from below the 8^0 discontinuity. Ray- tracing modelling shows that the delay at depth occurs near the transition from the plains to mountainous areas on the west-striking Early Rise lines. Therefore, we interpret the cause of the delay to be the transition between "cold" and "hot" areas at more than 150 km depth. The transition occurs over a narrow horisontal zone of less than 100 km width. It coincides with high-seismicity zones on all profiles, where observed. The coincidence between a transition in the upper mantle below ca. 150 km depth and zones of crustal earthquakes indicates, that the existence of such deep transition zones may have strong effects on the shallow, local tectonics.

SEISMIC EXPERIMENT ACROSS THE NORTHERN TIP OF THE ANTARCTIC PENINSULA (TENAP PROJECT)

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During the austral summer 1996-97, an offshore/onshore seismic experiment was carried out across the northern tip of the Antarctica Peninsula as part of the TENAP project (cenozoic Tectonic Evolution of the Northern Antarctica Peninsula), an Italo-Argentinian bilateral research programme in Antarctica. Three near vertical reflection seismic profiles (about 600 km in total) were acquired using a 3 km long multichannel streamer, and an air gun array source of 60.5 liters, operating in "single bubble" mode. In order to avoid the "wrap-around" effect on the wide-angle data, the profiles were re-shot with a 120 s shooting interval. The offshore energy was recorded by 15 portable seismic stations on the Peninsula and by 8 digital ocean-bottom seismographs (OBS) deployed in 16 positions along the lines. Offshore seismic investigation was complemented by gravity and magnetic measurements. Gravity measurements and geological observations were performed on the land continuation of the two main offshore-on land seismic transects. The "single bubble" seismic source allowed high penetration and good quality wide-angle data to be achieved for offsets larger than 100 km, on the Weddell Sea side of the AP.

STRUCTURE AND SEISMIC STRATIGRAPHY OF THE LOWER MOROCCAN ATLANTIC MARGIN OFF MESETA

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Deep seismic reflection data, collected in the Central Eastern Atlantic across the External Rifian Arc and Seine Abyssal Plain, image structure and stratigraphy of the lower portion of the Moroccan continental margin near the ocean-continent transition. This margin is non-volcanic and is characterized by wide half graben and faults blocks tilted westward by listric extensional faults. The half graben basins are filled by thick synrift sediments, including Late Triassic-Earliest Jurassic evaporites, and are overlain by a thick cover of postrift sediments. The thick sedimentary sequence shows a complex structure and stratigraphy and the most prominent sedimentary features are the giant salt diapirs that obscure the deeper crustal structures as well as the location and nature of the continent-ocean boundary. Seismic images also reveal that Tertiary compressive deformations, due to Iberia-Africa convergence, occur in the oceanic (?) and continental crust producing folding and erosion of the Mesozoic and Cenozoic sedimentary cover and a well-developed south-verging Neogene accretionary prism.

NH3 Earthquake risk mitigation (co-sponsored by SE)

01 Models and methods in seismic hazard assessment

Convener: Tsapanos, T.M.
Co-Convener: Christova, C.V.

THE NEW METHOD OF GROUNDS SEISMIC HAZARD DEGREE ASSESSMENT

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This work is the fillowing stage of elaboration of the new method of grounds seismic hazard assessment.
Revealing the factors on which the seismic danger of grounds depend (damping velocities of seismic waves, periods of more intensive part of oscillations of earthquakes, hypocentral distances and energy class of earthquakes) and defining the connection between these parameters separately for soft soils and rocks, the change of the degree of seismic danger which the change of these parameters for each ground condition turned out. Comparing quantitative descriptions for rocks and soft soils we obtained the degree of the increment of seismic intensity in compared ground conditions.

SEISMIC HAZARD ACCESSEMENT: NON PARAMETRIC TESTS TO ISOLATE SEISMOGENIC REGIONS

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Our study concerns the seismicity of Portugal and oceanic adjacent area. We use the I.G.D.L. seismic catalog updated in September of 1997. This catalog includes also the historical records of this region. Our starting hypothesis is that the catalog includes several earthquake populations, related to the different seismotectonic structures. To isolate each population we have to test if there is a statistical relation among several samples picked of the catalog. The testing must be performed in a non parametric basis. The catalog is divided into rectangular cells in order to define samples. Each sample is a sequence of pairs made of magnitude classes and frequency values. We pick two or more samples from the seismic catalog and test the null hypothesis that they belong to the same earthquake population. For each test, the cells must be neighbors of each other. The exhaustive testing along the catalog allows the evaluation of the limits of each seismogenic region: the related cells will join to be part of the same seismogenic region. For each of these coalescent seismogenic regions we plot the usual frequency-magnitude data, in order to evaluate the parameters of the Gutenberg-Richter law. This evaluation follows a robust fitting process.

VARIATIONS OF NEUTRON FLUX IN THE LOW ATMOSPHERE AND DEFORMATIONS IN THE EARTH CRUST

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Variations of thermal and slow neutron fluxes at the level of the Earth surface in the region of Moscow are observed on the plant, developed in the Institute, since 1993. We found out variations of neutron flux with amplitude up to thousands per cents and duration of dozens of minutes, which correlate with new moons and full moons. Cause of this phenomenon is influence of tide force of Moon and Sun and change of gravitation force gradient sign in this time. Formerly analogous phenomenon was detected by us in the seismoactive regions of Pamir.

MODEL OF SEISMIC LOADS DISTRIBUTION FOR THE KALININSKAYA NUCLEAR POWER PLANT SITE

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In order to estimate the seismic hazard level for the site of the Kalininskaya Nuclear Power Plant, which is on operation now, the seismic microzonation was carried out. The instrumental method was applied to construct the model of seismic loadsı distribution for the NPP site and the NPP main structures. The field observations included registration of microseisms and that of ground motions generated by non-explosive (pneumatic) source. 396 vertical component records of ground motions generated by the pneumatic source and 432 records of microseisms were obtained at 84 observation seismometric points both for free field and the main structuresı foundations. The estimation of seismic loads was made for three period ranges: from 0.5 up to 2.13 sec (0.47-2 Hz), from 0.3 up to 0.5 sec (2-3.33 Hz) and from 0.16 up to 0.3 sec (3.33-6.25 Hz). The local seismic sources, which are dealt with stationary technogenous sources of noise mechanical vibrations, were revealed on the basis of data obtained for technogenous changed soils under the condition of intensive industrial seismic noises. The quantitative estimations of seismic loadsı intensity for local sources of seismic noises allowed as a first approximation to exclude their contribution from the observed pattern when compiling the maps of seismic microzonation for the NPP site.

EXPERIMENTAL DETERMINATION OF RESONANCE FREGUENCIES OF LOOSE SEDIMENTARY LAYER

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The ratio of relationships 4H = nV/f (where n = 1, 3, 5, ..., V is a velocity of seismic wave propagation, and f is a resonance frequency of a layer), obtained according to P- and S-waves in one site, provides a curve with the first minimum corresponding to resonance frequency of S-waves, and with the first maximum corresponding to resonance frequency of P-waves. 10 earthquakes with epicentral distances less than 100 and K(9 are recorded in 3 sites located on hard frozen and detrital grounds (T(-1.80C) with an average thickness of 100 m at a dip angle of layer-halfspace boundary of 50, and in 3 sites located on permafrost rocky grounds (T(-30C). A high resolution of spectra on frequency was 0.5-0.75 Hz, and an error did not exceed 0.2. As a result of it, resonance frequencies were assessed. In the first site they were 1.7 - 2.3 Hz for S-waves and 4 - 5 Hz for P-waves, in the second site - 1.4 - 2.0 Hz and 3.5 - 4.5 Hz and in the third one - 1.1 - 1.6 Hz and 2 - 4 Hz for S- and P-waves respectively. An average ratio of resonance frequencies and, therefore, of propagation velocities of P-waves to those of S-waves was 1.6; 1.8 and 1.9. In average for a layer it was 1.75. The ratio of frequency characteristics of P-waves to those of S-waves, obtained for rocky grounds, showed that the components of wave fields, scattered on inhomogeneities, may significantly superimpose on seismic signals, especially at frequencies more than 5 Hz. The minimumsand maximums of the ratio of frequency characteristics is more expressed for earthquakes with epicentral distances less than 100 km.

EARTHQUAKE HAZARD MAPS AND STRONG EARTHQUAKES: ASSESSMENTS AND REALITY

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Traditionally the level of seismic hazard in some countries is measured in terms of intensity scale, and certain intensity values ("basic intensity") are assigned to every region by Building Codes to be taken as guiding principles in construction of public buildings. Strong earthquakes of M=7, occurred during last 20 years in the USSR and Russia, showed that the assessments of seismic hazard for regions of the events occurrence, must be revised, because the earthquakes were more severe than the Building Code provisions allowed for. We carried out new assessments of "basic intensity" using method of probabilistic seismic hazard estimation developed by the authors. The method is based on Cornell's (1968) procedures, and it incorporates into analyses information on ground motion, seismicity and tectonics, and allows to consider both regional and local features of seismic waves propagation. When employing the method, we used, as far as possible, the data on seismicity that were available before the earthquakes. Therefore, this study may be considered as a test of our approach and technique. The results demonstrate that our assessments of "basic seismicity" confirm the observed data, and they may be used as a reliable basis for Building Code provisions.

UNCERTAINTY IN THE ESTIMATION OF SEISMIC HAZARD AND DESIGN GROUND MOTIONS FOR NUCLEAR POWER PLANTS IN GERMANY

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Earthquake hazard has become an important issue for several nuclear facilities in Germany. The seismic design ground motion parameters for nuclear power plants in Germany have been determined using deterministic approaches in accordance with the existing regulatory requirement. The macroseismic intensity as basic parameter of the design earthquake was related to peak horizontal acceleration to scale the standard USNRC-spectrum (modified in the low frequency range). Design horizontal accelerations range from approximately 0.5 m/s^2 in Northern Germany to 1.5 - 2 m/s^2 for facilities along the Rhine.

Recent strong-motion-recordings indicate, that the standard response spectra used in previous years overestimate the low frequency content but underestimate the high frequency content of strong ground motions in Central Europe and other intraplate / low seismicity regions. Local soil conditions can have a larger influence than previously considered. The input parameters and assumptions for a seismic hazard assessment are connected with large uncertainties. It is important to estimate these uncertainties and their influence on the final result explicitly. Recent advances in the earth sciences require a seismic re-evaluation of nuclear power plants in Germany.

NATURAL AND TECHNOGENIC SEISMICITY ASPECTS FOR KUZNETSK BASIN OF ALTAY-SAYAN FOLDEN REGION

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The Kuznetsk basin (Kuzbass) is one of the major structure of the Altay-Sayan folden regions of the southern West Siberia. The great number of mines and enterprises plants are located here. The Kuzbass is a region of low seismicity, but there is a vexed question to assess regional seismic hazard. Powerful explosions are used there for mining purposes. At present seismicity activizing of this territory is observed. Since 1988 there was happen the series of seismic events caused significant macroseismic effects. This events are connected both with tectonic processes and with violation of the dynamic balance in the large mine(s) massif. Principal distinction between natural and tectogenic events are based on foci depth, location near or far from a mine and where or not the current shock rate deviate from background earthquake rate. The problem of the discrimination between earthquakes and chemical explosions is the main one of Kuzbass. We began to prepare the regional catalog of the earthquakes 1963-1995 years where being founding evident explosions and events with explosion-like waveforms are marked.

SEISMIC INTENSITY CHANGE ALONG SLOPS

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High seismic areas usually have complicated surface topography and it is important to define the seismic hazard change depending on influence of surface topography at the time of seismic events. Following the registrations of 300 earthquakes (k=8-12), change of amplitude and spectral comparisons in different points of slopes widh different approach of seismic radiation to the slop were defined. By means of spectra obtained in compared points, formulas allowing to define the coefficient of seismic effect increase for compared conditions were obtained.

EXTREME VALUES THEORY FOR MAPPING OF SEISMIC HAZARD IN ALBANIA

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Based on extreme value's theory (first and third Gumbel distributions) the mapping of seismic hazard in space and time was performed for the territory of Albania. Missing events of smaller magnitudes were considered based on normalized seismic activity maps. It was considered that despite of lack of important seismic events in particular regions during the particular periods, normalized seismic activity maps showed that there is a continuous seismic background which has to be taken into consideration during the assessment of seismic hazard for a particular region. The outputs of studies carried out, were presented through the maps of maximum expected earthquakes and total magnitudes(or total energy released during the particular period of observations taken into consideration for computation purposes). Comparison of observed and predicted events showed a good coincidence for some particular regions and the importance of great linear foci, which are characteristic for Albania, in the seismic hazard assessment procedures.

DATA SEISMIC ANALYSIS AND MODEL OF EARTHQUAKE PREDICTION AT THE CHERNOBYL (NPP) LOCAL ZONE

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Discussed the problem of short term forecasting of local seismic events nearby Chernobyl NPP. Authors developed the automatic system of monitoring and provided long term investigations of the Chernobyl NPP (object Shelter) in seismic frequency band. Obtained results allowed build the mathematical model of object reaction on external seismic disturbance and the model of seismic activity prediction. These models used for controlling seismic safety and short term predicting of possible local seismic events. The system further development is supposed to provide quick access ability for the experts to the registered data. To provide maximum access ability to the experts from different countries special Internet node is planned to be organised. This node is to support data base with operative information about local seismic activity on the territory nearby object Shelter. Contribution gives results of practical realisation of this scientific work.

THE IMPACT OF *b* VALUE UNCERTAINTY ON LOSS ESTIMATION IN THE REINSURANCE INDUSTRY

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In reinsurance industry different probabilistic models are currently used for seismic risk analysis. A credible loss estimation of the insured values depends on the seismic hazard analysis and on the vulnerability functions of the given structures. Besides attenuation and local soil amplification, the occurrence model (often represented by the Gutenberg and Richter relation) is a key element in the input of the analysis. However, earthquake catalogues are usually incomplete or the time of observation is too short and since the data itself have errors, *a* and *b* values can only be estimated with uncertainties. The knowledge of their standard deviation provides a valuable input for earthquake risk analysis, because they allow modeling the probability distribution of expected losses (expressed by average annual loss (AAL)).

Magnitude uncertainties have a direct effect on the estimated *b* values and consequently on the calculated probabilities of occurrence. This effect is best illustrated by magnitude vs. AAL graphs, where the sensitivity of average annual losses due to different standard deviations of *b* is obvious. Thereby, the variations of event occurrence probability due to the uncertainty of *b* are used to quantify a confidence range and the standard deviation of average annual loss.

The estimation of the standard deviation of *b* and the quantification of the sensitivity of AAL are fundamental for an optimal earthquake risk management. Ignoring these uncertainties means that risk management decisions neglect the probabilistic character of the earthquake loss estimations.

SWEDISH PALEOSEISMICITY AND VARVE DATING

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Today, Fennoscandian is characterized be a low to moderatly low sesmic activity. At the time of deglaciation, the situation was quite different, however. The region was then characterized by both large and frequent earthquakes. The rate of isostatic uplift then amounted to some 10 cm per year (i.e. about 10 times as high as the present sea floor spreading rates). In Sweden, we have the possibility of utilizing the varve chronology for the dating of paleosesmic events. This means that we can achieve an annual resolution despite ages in the order of 10,000 years. This technique has successfully been applied to some regions in Sweden. In the Stockholm region, we have been able to date an extremely large paleo-seismic event to the autumn of varve year 10,430 BP. This event caused liquefactions and varve disturbancies over an area of about 60 x 320 km, which seems to indicate that we are dealing with a magnitude above M 8. We have also been able to identify multiple events re-occurring about every 20 varve (~10,490, 10,469, 10,447, 10,430, ~10,410 BP). A Holocene event occurred along the same fault zone at about 3500 BP. At Iggesund, we have recorded heavy bedrock deformations in association with strong sediment deformations from both ground shaking and tsunami waves, and turbidites over an area of 60 x 210 km at varve 9663 BP.

SEISMOTECTONIC CONSTRAINTS ON THE MAXIMUM CREDIBLE MAGNITUDE USING THE GAMMA DISTRIBUTION.

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Recent statistical mechanical and cellular automaton models of earthquakes as self-organised critical phenomenon demonstrate that the most general form of the frequency-magnitude distribution is the gamma distribution, constrained by the mean seismic moment release per event $<M>$ and the maximum magnitude m_{max}. This allows a credible maximum magnitude m_{max} to be defined independently by a negligible contribution to the total seismic moment release. Here we apply this method to seismic hazard in the mainland UK and its immediate continental shelf, where the gamma distribution - constrained by a mixture of instrumental, historical and neotectonic data - is used to extrapolate the frequency-magnitude distribution and determine a maximum credible magnitude. m_{max} is found to be in the range 6.3-7.3 for the truncated Gutenberg-Richter law, or 7.0-8.0 m_L for the gamma distribution, compared to a maximum observed in the time period of interest of 6.1 m_L. The upper bounds are conservative estimate based on 100% seismic release of the observed vertical neotectonic deformation, primarily due to glacial rebound, projected onto a single fault. Glacial rebound is predominantly an elastic rather than a seismic process, and the seismicity in an intraplate area such as the UK is likely to remain distributed in space rather than concentrated on a single dominant fault, so the true value of m_{max} is likely to be nearer the lower end of the quoted ranges.

REVISED WORLD SEISMICITY CATALOG (1950-1997) FOR STRONG ($Ms \geq 6$) SHALLOW ($h \leq 70$ KM) EARTHQUAKES

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Using the earthquake catalogs provided by the International Seismological Centre and the National Earthquake Information Center, we analyze the world-wide consistency of teleseismic reporting, completeness of the seismicity record and homogeneity of magnitude determination, for strong ($Ms \geq 6$) shallow ($h \leq 70$ Km) shocks in the period *1950 to 1997*. Under the postulates that the rate of earthquake occurrence for the entire world is constant on a time scale of decades, and that for the last three decades the earthquake catalog for strong shocks is complete and the corresponding seismicity rate is typical of all periods in the century, we find that, due to the use of different formulations and criteria to calculate the parameter "magnitude", the *Ms* of moderate ($6 \leq Ms < 7$) events in the period *1950 to 1963* were systematically overestimated by as much as 0.5 unit, relative to the *Ms* assigned to shocks occurring after *1963*. When this correction is taken into account, the new catalog of events with *Ms(corrected)* ≥ 6 in the period *1950 to 1997* becomes largely homogeneous in *Ms*. Under the postulates above, this new catalog is shown to list all and only the strong shocks (*Ms(corrected)* ≥ 6; $h \leq 70$ *km*) that occurred in the earth during the period, a notable exception being the time span from *1964 to 1968*. The revised catalog, including the scalar moment for each event, will be released at this meeting.

RELATION OF TYPICAL EARTHQUAKE LOSSES WITH ECONOMICS DEVELOPMENT

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Data on victims and losses caused by earthquakes in 1900-1996 years were examined in connection with economic conditions in different regions. The completeness of the catalog was examined. The number of events that had caused small or moderate number of victims increases with time in a non-linear manner; whereas the number of events with large losses has a linear increase in time. The rates of events for different loss and victims ranges are similar for developed and less developed countries but with a lag in time. Some relations of typical earthquake losses with economic parameters are derived and discussed.For example, the average ratio of economic loss to victims number caused by earthquakes being normalized to the national income per diem is nearly constant. The Pareto-law distribution of losses produces a non-linear increase of total loss with time. The change from the non-linear behavior of cumulative loss to linear one with increase of observation time is discussed.

EARTHQUAKE RECURRENCE FOR NORTH EURASIA: THE THENCHING DATA

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The trenching method in paleoseismic investigation is very popular recently due the reliable and informative results. Some seismic faults of earthquakes of historic and instrumental periods were studied by this technique. For example three trenches were dug across the surface rupture of the Mogod, 1967, Ms=7.8 earthquake on Central Mongolia and two trenches were dug across the visible escarp of problematic paleoruptures of a prehistoric earthquake in Altai. The main results of these researches are: 1. The strong and major earthquake sources are stable structure in geological environment due to the special combination of geological and geophysical condition. 2. Seismic shocks occur in the same source zone repeatedly. 3. An average recurrence period depends on structural and geological condition (in Alpine fold system-several hundred years, in young and ancient platforms-several dozen thousands years.

TIME DEPENDENT SEISMICITY IN CHINA

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The regional time and magnitude predictable model has been proved to be the most appropriate one in describing the behavior of strong earthquakes occurrence in all the regions of the continental fracture system (Papazachos *et al.* 1997). It is expressed by the following relations:

$$\log T = 0.19M_{\min} + 0.33M_p - 0.39\log m_0 + q$$
$$M_f = 0.73M_{\min} - 0.28M_p + 0.40\log m_0 + m$$

where T is the time period between two main shocks; M_p the magnitude of the previous main shock; M_f the magnitude of the following main shock; M_{min} the magnitude of the smallest mainshock; m_0 the moment rate in each region, and q and m are parameters which change from area to area. Based on the seismotectonic and other criteria, the territory of China was divided into 66 regions and the above model has been applied with the aim to estimate the probability of occurrence of the next strong mainshock ($M\geq7.0$) during the next decade as well as the magnitude of the expected event. In order to compare the results obtained by the model with the results derived by the time independent model, statistical tests have been performed. It was found that the "model probability" is almost equivalent to the rate of occurrence of the mainshocks in each area. Furthermore, the success ratio of the model probabilities was found to be more compatible with the real situation than the one estimated by time independent models.

The model of the seismic process and prognosis of the earthquakes.

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Many dynamic, deformational and rotational features of the Earth, created by the outer and inner forces, have been formed as a result of the interaction of its model parts. In particular, the deformation exceeding the rocks (tensile strength) can happen during 50-600 years, which is the period of earthquakes (EQ) repetition in the varies seismic regions of the Earth. As it is known, EQ are related to solar activity. Its 11-year cycle (s.c.) can be used as unit in Wolf's digits, and the analysis of the EQ distribution during the recent 100 years shows that the period between the EQ of M>8 is 6 s.c., and if M=7.0-7.9 the period is 5 s.c. Inversion of the seismic activity migration occurs during 2 s.c. Analysis of the seismic activity migration at some territory shows that the EQ hypocentre shifts in longitude and for some distances, and such displacement are different depending on the EQ's magnitude. The EQ's magnitude is usually proportional with the square of the spherical surface ,where the outer forces influence the Earth, and its inner reaction against those forces is in action. The radius of that surface (R) can be calculated as $M=Lg(nR^2)$, where R is in km. An example of the prognosis can been seen below. The forecast was done on the 12th of June, 1995, for the second half of 1995. The possible seismic event was expected by the end of 1995 in a place with coordinates $79^0\pm1.5^0$E, $42.5^0\pm0.5^0$N, $M=5.5\pm0.5$. The actual EQ occurred on the 31th October, 1995, at $80^0\ 10^1$E , $43^0\ 10^1$N, M=5.0-5.1. At the same time the conclusion had been made that EQ of $M\geq6$ could not be expected in this area in 1995. That prognosis had proved to be correct. There is a new theoretical basis of EQ prediction .

DETERMINISTIC SEISMIC HAZARD ASSESSMENT OF ROMANIA

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The seismic hazard is described by peak ground motion values (acceleration, velocity or displacement) and design ground acceleration. Synthetic seismograms are computed by normal mode summation for a dense grid of sites covering the whole territory. The computation is made separately for shallow and intermediate-depth sources. Special attention is paid to Vrancea earthquakes which prominently control the distribution of the hazard level. The peak ground motion parameters are compared with the discretized existing maps of macroseismic intensity reported for the large Vrancea earthquakes. Regressions between the maximum observed intensities and synthetic peak ground motion are analyzed. The influence of the focal mechanism in the Vrancea source upon the characteristics of the macroseismic field is investigated. The results of our deterministic approach are finally discussed with respect to other approaches employing the probabilistic method.

METHODS FOR ATMO-RADIOGEOCHEMICAL MONITORING OF MANIFESTATIONS OF SEISMO- TECTONIC HAZARDS

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Presented are combined methods applied to monitor possible activization of endogenous geoprocesses. Areas with high ecological risk are isolated - specific geodynamic deep-seated zones featuring abnormal geochemical and fluidal regime, and abnormal seismic (active seismic generating faults). The study of neogeodynamic processes is based on the high-informative regional and local airborne survey, particularly, examination of the distribution of methane, radon, uranium, thorium, and potassium found from atmogeochemical and gamma-ray spectrometry made at the altitude of 50-75 m. Airborne equipment includes laser methane gas analyzer with the sensitivity of 0.1 ppm, combined with microprocessor ADSP-2101; radon analyzer which provides measurement of alpha-radiation of atmospheric aerosol sorbed by air filters, airborne gamma-ray spectrometer, etc. Measuring devices are interfaced to navigation units controlled by a computer providing data acquisition, recording and processing.

ESTIMATION OF EARTHQUAKE HAZARD PARAMETERS IN THE SOUTH AMERICA AREA

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Two techniques are applied in order to estimate the earthquake hazard parameters in South America, an area of high seismic activity. These techniques are: 1) the ω values obtained through Gumbel's third asymptotic distribution of extremes, which is considered as the upper bound magnitude and is related to the finite maximum stresses and strains which are currently accumulated and released by the rocks, as earthquake, in a region; and 2) the maximum likelihood approach. This second one provides the regional maximum magnitude. Mmax (which is considered as the maximum possible magnitude in a specific region), the actiivity rate, λ, of the seimic events. the mean return period, R, of earthquakes with certain lower magnitude M≥m and the parameter b of the magnitude-frquency relation. The parameter β is also obtained. which is interrelated to b, with b=βloge. Six depth-ranges subdivisions are defined for the examined area. All the seismic parameters are computed for each individual depth range. In all cases ω values are higher than the regional Mmax estimates. The seismic activity rate is decreasing with depth, while β parameter, which ranges between 1.18 to 2.06, does not show any regularity in its depth distribution. Based on the obtained parameters, we evaluate the seismic hazard of each depth range in South America.

FROM QUANTITATIVE SEISMIC ZONING TO THE DEFINITION OF CORRELATION RELATIONS BETWEEN GROUND MOTION PARAMETERS AND MACROSEISMIC INTENSITIES

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A deterministic procedure for seismic hazard assessment has been developed at the University of Trieste, Dept. of Earth Sciences, in the framework of the activities of the Gruppo Nazionale per la Difesa dai Terremoti. Using the available information about regional structural models, past seismicity, and the seismotectonic regime of the studied area we generate by the modal summation technique a set of synthetic seismograms covering the territory on a 0.2° x 0.2° grid. The procedure has been recently applied in the Circumpannonian and Dinaric region, and in Algeria. Peak values of ground motion (displacement and velocities) and Design Ground Acceleration based on design spectra extracted from the synthetic signals, can be compared with observed macroseismic intensities wherever reliable intensity maps are available. This is the case of Italy: the correlation relations that we have obtained are in a good agreement with empirical relationships given by other authors and compare quite well with the few observations available in the Italian territory.

A WORLDWIDE SEISMIC HAZARD ASSESSMENT

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The most reliable data set is used in the present study in order to evaluate the seismic hazard in the whole globe. The data set consisted of a complete and homogeneous global catalog of earthquakes with magnitude Ms≥5.5 and the time covered is from the beginning of the present century. The present study is restricted to shallow (h≤60 km) earthquakes. In order to produce maps of seismic hazard, the whole Earth is divided into a grid point mesh 1°X1°. For each 1° point the parametrs a and b were estimated by least squares method and using a sample of data of earthquakes located inside circles centered at each point. The radius of the circles varied, starts from 30 km and is moving with a step of 10km. Only those values of a and b are accepted which fullfilled 3 predefined condiitions. These are : 1) the number of earthquakes in the circles must be 15 or larger, 2) the number of points in the LogN-M must be 5 or larger and 3) the difference between the maximum and the minimum magnitude of earthquakes in a circle must be 1.5 or larger. Based on these we prepared maps of seismic hazard which is expressed as Mmax observed and cóncequently as seismic moments and seismic moment rates. These maps effectively produce a brief atlas of seismic hazard.

B-VALUES FOR ESTIMATING RECURRENCE TIMES: AVERAGE OR ASPERITY VALUES?

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The b-value varies strongly on scales of a few kilometers in most seismogenic vol-umes we have mapped so far by the gridding technique. This is not unexpected be-cause the crust is heterogeneous in material properties and in stress level. One should expect the mean magnitude, or mean rupture length, to vary from volume to volume. These variations are reflected by the change of b-value, which is inversely propor-tional to mean magnitude. Along segments of the San Andreas and the Calaveras faults, we have found that anomalously low b-values of 0.5 correlate with asperities and anomalously high b-values of 1.3 with creeping segments of the fault. Therefore, we hypothesize that seismogenic volumes with anomalously high b-values may not be able to generate major earthquakes; they may only participate relatively passively in major ruptures of neighboring asperities characterized by low b-values. Along the San Andreas fault, we find that the recurrence time is overestimated by three orders of magnitude if it is based on the frequency-magnitude relation (FMD) of the creeping portion, by a factor of four, if it is estimated from the average FMD, and it is estimated correctly from the FMD within the asperity only. We propose that the portions of a fault outside the asperities do not contain information on when rupture may occur, be-cause this is controlled by the asperity exclusively. If our ideas are correct, then recur-rence time calculations based on FMDs should be revised to include asperities only.

A HOMOGENEOUS MARKOV MODEL AS A PATTERN FOR EARTHQUAKE RECURRENCE IN SOUTH AMERICA

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The well known statistical model of the Markov-chains is applied in South America in order to search for a pattern of great earthquake recurrence. The model defines a process in which successive state occupancies are governed by the transition probabilities p_{ij} of the Markov process, and are presented as a transition matrix of NxN dimensions. The process $\{X(t), t\geq 0\}$ describes the visits to the states and is said to be a Markov process. The magnitudes of earthquakes are firstly defined as states and the obtained results indicate an evidence for a homogeneous behavior of the model, which was verified by the application of the x^2-test. The six predefined zones in which the area of South America is divided are then considered as states. Thus the visits from zone to zone. which is from state to state, carry with them the number of the zone in which they occurred. If these visits are considered to be earthquake occurrences we can inspect their migration between the zones (states) and estimate their genesis in a statistical way, through the transition probability. Attention is given in the zones where the large earthquakes with M≥8.0, in 1906, 1922, 1942 and 1960 occurred. A pattern is revealed which suggests a south towards north migration of large earthquakes. The migration (visit) from zone to zone (from state to state) is given through the estimated transition probabilities.

AN INTEGRATED SYSTEM FOR SEISMIC RISK ASSESSMENT OF VRANCEA REGION- ROMANIA

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The aim of this paper is to present an integrated data system based on satellite remote sensing , geotectonic, "in-situ" monitoring data for seismic risk analysis which estimates the geographic distribution, frequency, and intensity of seismic activity, without attempting to predict specific events.Remote sensing and field studies of active faults can provide a geologic history that overcomes many of the shortcomings of instrumental and historic records. The majority of strong Romanian earthquakes has the origin in Vrancea region, a distinctive active zone of the Alpine orogenic belt placed at the Eastern Carpathians Arc Bend with extensive macroseismic area.GIS/LIS technologies are very useful for a more powerful analysis and decision support tools.

NH3 Earthquake risk mitigation (co-sponsored by SE)

02 Seismic hazard evaluation in high seismicity areas by observing precursory phenomena

Convener: Contadakis, M.E.
Co-Convener: Zschau, J.

Sponsorship: Department of Surveying and Geodesy, University of Thessaloniki, GeoForschungsZentrum Potsdam

AN "BOUNDARY DILATANCY LAYERS" AND THEIR INFLUENCE ON THE RELATION BETWEEN GEOPHYSICAL ANOMALIES-PRECURSORS OF DIFFERENT NATURE

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The space-time variations of anomalies of geophysical fields (stress and strain fields, the gravitational field; distribution of the electrical resistance, the ground water level, etc.) in formation of sources of future earthquakes can be recorded using dense geophysical multidisciplinary observation networks. These anomalies appear at distances of up to 200-300 km. Their behaviour is very unstable. There arise some questions associated with elucidation of the formation mechanisms of these anomalies. Some of these questions are discussed within the framework of the hypothesis for dilatancy of the near-surface layer of the Earth's crust. It has been established by mathematical simulation. The formation of "conjugate" anomalies of geophysical fields in zones of "surface dilatancy" and the corresponding direct and inverse multidisciplinary problems of mathematical simulation of the anomalies are considered.

A NEW APPROACH TO USING THE DATA OF ELECTROMAGNETIC MONITORING OF EARTHQUAKES AT THE TERRITORY OF CHINA

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Seismologists in different seismically active regions of the Earth use, as a rule, the whole set of geophysical methods taking into account the complex character of seismicity processes. It is well known that anomalous changes of different geophysical fields taking place before many strong earthquakes can apparently be considered as precursors of earthquakes. However, in a large set of such precursors there are always contradictory data about the possibility of an earthquake and its parameters. One significant limitation of available prediction algorithms based on studying the development of anomalies of various nature is basically the statistical character of these algorithms. They practically do not take into account the quantitative characteristics of the physical process of earthquake preparation itself. An attempt is made to use the data of monitoring of electromagnetic precursors of earthquakes made available to us by Chinese specialists for reconstructing the time dynamics of some characteristics of the medium in the regions under observation. The analysis of real data has shown that effective parameters of cracking can be reconstructed within the framework of the Archies law with some certainty. In any case, the obtained estimates of the effective parameters associated with the cracking of the medium correlate well with the time of earthquakes.
(The research was supported by RFBR under grant 96-05-66058.)

THE EARTH'S CRUST DEFORMATIONS MONITORING ON KAMCHATKA.

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The Kamchatka Peninsula is located at the junction of the Aleutian and the Kurile-Kamchatka island arcs. This region is characterized by high volcanic and seismic activity. Geodetic monitoring of Petropavlovsk-Kamchatsky and it's vicinity by laser distance measurement, strainmeter and tiltmeter had been made since 1978 year. Observations are carried out by one-wave and two-wave electronic distance measurements, borehole strainmeter and tiltmeter. The main results obtained from 1978 are as follows: - elastic anisotropic deformations about 3 ppm were observed; - measured deformations were revealed to be interrelated with both earthquakes and volcano eruptions; - trends of line lengths with velocity of about 0.03-0.2 ppm/year were detected; - the Avachinsky volcano eruption of January 13, 1991 was accompanied by 3 ppm deformations; - deformation wave from Hailino earthquake (M=7.0, March 8, 1991) was registered at a distance of 1000 km from epicenter. Its velocity and amplitude were 40 km/h and 1 ppm, correspondingly; - coseismic deformations 0.8 ppm and 100 mkr from the Shikotan earthquake (October 5, 1994 M=8.0) were obtained; - the reactions of strain and tilt from earthquakes of Sanriku (29.12.94),Kobe (17.01.95),Sakhalin (28.05.95) were noticed. - precursor variation of strain before Neftegorsk earthquake appeared several days before and had an amplitude of about 3 ppm. The observations by GPS stations were started in 1995. The continuously observations began in summer 1996. There are 8 GPS stations on Kamchatka now for studing of Earth's Crust Deformations as precursory phenomena before high seismicity. Only one strong earthquake (05.12.97, M=7.7) not far from Kronotski penisula was from summer 1996. Any data of GPS stations as a reaction from this earthquake will be represented.

CURRENT SEISMIC HAZARD , ASSESSMENT BASED ON MULTIPARAMETER MONITORING OF LITHOSPHERE

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Long-standing investigations of pre-, co-, post- and inter- seismic phenomena on the territory of Armenia, based ón the multiparameter monitoring of lithosphere shows the following: 1) anomalous geophysical, geological, . biophysical phenomena accompanying the preparation and realization of seismic events in general are not related to the earthquakes, they like the earthquakes themselves are related to the Earth's crust deformation under the influence of regional forces of the elactic stresses. 2) The stronger is the Earth's crust deformation, the greater is the value of the anomalies of geophysical geological, biophysical accompanying the earthquake preparation and realization pocesses. 3) In connection with the Eatrth's crust heterogeneity, its maximum deformation zones in general case, may not coincide with the rupture zones, i.e. with the eathquake source. 4) The anomalies of geophysical, geological, biophysical phenomena, acompanying the seismic event preparation and realization due to the heterogeneity of the Earth's crust. may be observed at any distance from the rupture of zone (i.e. from the earhquake source) within the entire regional field of deformations; Therwith the anomalies of various phenomena in may be more intensive in the zone which is far from the source than in the one which is near to it. In contrics like Armenia today it is more realistic and necessary to focus the national effects on stage-by-stage current sesmic hazard assessment.

RESONANT DISTURBANCES IN A HOMOGENEOUS ELASTIC WAVEGUIDE AND EARTHQUAKE PREDICTION

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We show that every homogeneous elastic waveguide is neutrally stable and possesses a countable set of temporally resonant frequencies $\{\omega_n \in \mathbb{R}, n \in \mathbb{N}\}$. For each ω_n in this set, the response of the waveguide to a spatially localised two-dimensional (2-D) oscillatory forcing, with the time dependence $e^{-i\omega_n t}$, grows in time at least as $\sqrt{t}$, for $t \to \infty$. The growth $\sqrt{t}$ occurs in the case of a low-order resonance. Also, for a wide set of physically relevant waveguides, there exist resonant frequencies $\tilde{\omega}_m \in \mathbb{R}$, for which high-order 2-D resonances with the growth $t^{3/4}$ occur. Same $\tilde{\omega}_m$ are resonant frequencies for axisymmetric disturbances, with the growth $\sqrt{t}$. The analysis is based on solving the linear initial-value problem for localised disturbances in the waveguide by means of a combined Laplace-Fourier or Laplace-Hankel transform. The asymptotic evaluation of the solution, when $t \to \infty$, represented as an inverse transform integral, is carried out by analysing the spectrum of the waveguide $\{(k,\omega) \mid D(k,\omega) = 0\}$, for $(k,\omega) \in \mathbb{C}^2$. Here k is a wavenumber and $D(k,\omega)$ is the dispersion relation function. Low-order resonances occur for a frequency $\omega_0 \in \mathbb{R}$ for which the equation $D(k,\omega_0) = 0$ has a double root $k_0 \in \mathbb{R}$ in k. In the high-order case treated the root is quadruple. Algebraically growing disturbances can play a role of a triggering mechanism for certain earthquakes. So computing and observing resonant frequencies can lead to a prediction of such earthquakes.

DETECTING PRECURSORY SEISMIC QUIESCENCE IN GREECE USING THE SEISMOLAP METHOD

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SEISMOLAP was introduced by Zchau (1995) in order to quantify seismic clustering and quiescence at one location with one variable. The application of SEISMOLAP to the Greek earthquake catalog of the Institute of Geodynamics of the National Observatory of Athens successfully identified precursory seismicity quiescence prior to five catastrophic earthquakes that occured in different areas of Greece in the last twenty years (Chouliaras et al., 1997). In this study, for a better evaluation of the method, we will present a more thorough investigation by testing it with a larger number of seismic events in order to perform statistical analysis on the results.

OBSERVATIONAL EVIDENCES OF GEOELECTRICAL AND SEISMOACOUSTIC SIGNALS POSSIBLE RELATED TO SEISMIC ACTIVITY ON SOUTHERN APENNINE CHAIN (ITALY).

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The first experimental results regarding a combined monitoring of geoelectric and seismoacoustic signals in a seismic area of Southern Italy are analyzed. A remote station was installed north of the town of Potenza, close to an active fault system, where many destructive earthquakes occurred in past and recent times. The goal is to verify the existence of correlations between geoelectric and seismoacoustic signals and the local seismicity. Preliminary filtering procedures for the removal of meteo-climatic effects and noise fluctuations of anthropic origin were applied. Then, objective methods were used to discriminate anomalous patterns from background noise in electric and seismoacoustic time series. Finally, a deep analysis of the possible correlations between extreme events and incoming earthquakes has been carried out. The results so far obtained encourage the prosecution of the research to improve the knowledge on the local geodynamic processes that give rise to precursory phenomena of electric and/or acoustic nature.

STUDY OF SEISMICITY IN GREECE AND THE ADJACENT AREAS BY THE SEISMOLAP METHOD

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The paper deals with space-time distribution of seismicity in Greece and the adjacent areas. The applied **SEISMOLAP** technique (Zschau) gives new measures of seismicity **(SEISMOLAP1)** and quiescence **(SEISMOLAP 2)**. The advantage of **SEISMOLAP** in search for precursory information is that it considers both frequency of earthquakes and their distribution in time and space relatively to a point of investigation. A newly developed reference system which allows statistically significant clustering and quiescence to be recognized is applied. Several fault zones in the considered region are investigated by using various versions of **SEISMOLAP**.

PRECURSORY SWARMS, QUARMS, AND MAINSHOCK HAZARD

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Systematic studies of the predictive relations between swarms and mainshocks, based on the New Zealand and Japan catalogues, have indicated that the state of uniformity of the medium is a factor in seismogenesis, and that the occurrence of swarms depends on high fluid pressure. An implication of these developments is that, in regions of lower fluid pressure, the swarm is replaced by the quarm (i.e. quasi-swarm), which is more protracted in time, but is otherwise similar, and displays the same predictive relations. The performance of these precursors is being tested by the methodology of hazard refinement and synoptic forecasting.

RESEARCH FOR GEOHYDROLOGICAL SEISMIC PRECURSORY PHENOMENA IN GREECE

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Although reliable reports on pre-, co- and post-seismic variation on hydrologic characteristics of a seismic active area were known from the antiquity in Greece, it was only the last two decades that systematic research focused its interest to this potential method on estimating the seismic hazard. These investigations are briefly reviewed and the results are been discussed together with the results of the recent research on underground water level and temperature, which has been undertaken by the Department of the Geodetic Astronomy in the area of Pieria in Macedonia, Greece(22°.6E,40°.2).
From this discussion it turns out that underground water level and temperature variations were clearly observed as precursory phenomena connected with major earthquakes as well as as increased noise connected to the local microseismic activity with a probability 75%. In view of these results we conclude that, among the various methods of indirect monitoring of the tectonic activity in an area, which in addition is of very low cost, is that of the following up of the underground water level and temperature changes in the area of interest. This method is based on the fact that tectonic activity result to tectonic stresses producing alterations to the local water table which in its turn is observed as variation to the underground water level and temperature.

CRUSTAL MOVEMENTS OBSERVED IN THE FOCAL REGION BEFORE AND AFTER THE 1995 HYOGO-KEN NANBU EARTHQUAKE (M=7.2)

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Continuous observations of crustal strain, tilt and underground water discharge have been carried out at 2 stations in Kobe, Japan, which are located within the focal region of the Hyogo-ken Nanbu earthquake. At the Rokko-Tsurukabuto station, large strain and height changes caused by the earthquake were observed. Short-term changes particularly before the earthquake were not detected, but a slow decrease of strain rates and a relative upheaval continued for a long time prior to the earthquake. After the earthquake, the Otsuki fault crossing the observation tunnel started dislocations of a rate of 0.1-0.2mm/year. At the Rokko-Takao station, large strain changes and increase of discharge were observed about 3 months before the earthquake,. At the time of the earthquake, a large strain step occurred and discharge increased by a factor of about 6. The strain and discharge recovered to the previous levels about 4 months later.

STRAIN AND TILT CHANGES OBSERVED IN THE 800M BOREHOLE NEAR THE NOJIMA FAULT IN AWAJI ISLAND, JAPAN

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After the 1995 Hyogo-ken Nanbu earthquake (M=7.2), 3 boreholes, 500, 800 and 1800 m deep were drilled into the seismic source fault. In the bottom of the 800m borehole, a new multi-component borehole instrument was installed on May, 1996. We observed a secular strain of extension in the NE-SW direction and a secular tilt sinking toward the SW direction. The direction of these strain and tilt is the same as the fault strike. The strain change also showed undulations with periods of 2-3 months, with after-shocks (M¿3) tending to occur in periods of extensional strain. In an experiment of high pressure water injection into a fault gauge section in the 1800m borehole, we observed clear changes of strain and tilt caused by the water injection. The strain indicated compression as the injection commenced and recovered when the injection closed. In addition to these controlled experiments, strain and tilt changes also recorded daily variations reflecting pore pressure change.

THE FORECASTING FEATURE PREDICTIBILITY COEFFICIENT CONSTRUCTION.

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It is evident that the relation between the seismical events (s.e.) and any of its forecasting feature (f.f.) of anyone geophysical field can not be simple because of very complicated processes of s.e. evolution and the influence of many nonseismical factors on the considered geophysical field as well. So the time gap between the f.f. manifesting and the s.e. is of rather wide range, as well as there are part of s.e. without f.f. and part of manifested f.f. without the following s.e.

The author propose to evaluate the prospectivity of f.f. by the help of so called forecasting feature predictibility coefficient k_p. For the sake of time of s.e. prediction the proposed coefficient has the next construction

$$k_p = \max_{\{k(T),k(T/l)\}} \sum_{j=1}^{N} R_j \Big/ (R_{id}\, N) \qquad (1)$$

where N - the complete number of manifested f.f. and s.e.;
$R_j = \left[oz(\delta T_j / T)\cdot k(T/l)+1\right]\cdot\left[L - k(T)\cdot(\delta T_j/T)\right]$; $R_j=0$ if $R_j<0$; $R_{id}=R_j(\delta T_j=0)$; $oz(\delta T_j/T)=0.or.1$ if $\delta T_j/T>1$or elsewhere, corresponding. In abovewritten expressions δT_j - the time error gap between f.f. manifestation and s.e. T - the scale factor; l - scale factor corrector; L - level, depending of the type of prediction (long-, middle-term and so on). k(T), k(T/l) have to be determined according to maximizing condition in (1).

RTL PROGNOSTIC PARAMETER: APPLICATION TO THE STUDY OF SEISMICITY OF ITALY

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A prognostic parameter of strong earthquakes RTL have been proposed some times ago (G.Sobolev, Yu.Tyupkin, 1996a) The idea of the proposed approach is based on the supposition that two stages consecutively follow one another in the focus of a future earthquake, i.e., the quiet stage and the foreshock activization of seismicity; In this process, the quiescence almost always occurs during the stage of accumulation of seismic energy in the course of earthquake preparation. The methodical indication for realization of algorithm of calculation of parameter RTL was the supposition that in the immediate vicinity of the epicenter of the future earthquake the mentioned effects are the stronger the nearer is the moment of its occurrence. The tentative retrospective calculations of this parameter by the example of several strong earthquakes (M>7) on Kamchatka, in Caucasus, in Greece produce satisfactory results. In the present report the results of RTL analysis of earthquakes with M>4.5 occurred in the Reggio Emilia area (Northern Italy) and disastrous earthquakes occurred in the Central Italy on September 1997 are discussed.

ANALYZING THE GEOCHEMICAL INFORMATION FOR EARTHQUAKE PREDICTION

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This paper discusses the geochemical information for Earthquake prediction. We have a large database of geochemical information. It includes many geochemical elements from many stations during many years. The first is analyzed the homogeneous dates (very important part is that they should had adequate equipments and methods in time). The second part is restoration of missing dates. We use new methodology for restoration missing dates. For analyzing the precursors behavior we divided dates three parts in time : before Earthquake, Earthquake and Foreshok, and after Earthquake. By correlation analysis were finded interesting results for Earthquake prediction.

INVESTIGATION OF TENSELY-DEFORMED STATE IN HIGH SEISMICITY AREAS USING VIBROSEISMIC SOURCES

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The paper deals with the results of the Russian-Japanese experiment of 1995 on studying the structure of vibroseismic fields of powerful sources and a connection between these fields and the tensely-deformed state of the geological medium. Vibrational seismograms and spectra of harmonic signal were obtained on a profile up to a distance of 320 km. They contain information about the Moho boundary and the crust structure in the region of the experiment. The experiment has shown that changes in the stressed state of the medium in seismic-prone zones can be studied using variations of the dynamic characteristics of seismic waves, which pass from a powerful vibrational source through the area of earthquake preparation. A concept of the active vibroseismic monitoring system for seismic-prone zones with heavy vibrators and distributed field seismic arrays is presented.

SEISMIC-QUIESCENCE PRECURSOR OF EARTHQUAKE ACTIVITIES IN ASWAN AND GULF OF AQABA REGIONS AS ESTIMATED BY THE SEISMOLAP METHOD

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On the basis of the seismolap method, which is recently introduced by Prof. J. Zschau from the GeoForschungsZentrum Potsdam, Germany, the earthquake activities along the Kalabsha fault in Aswan and the Gulf of Aqaba regions, in Egypt are investigated in the present study. Aswan earthquake data were recorded and located by the Aswan telemetered seismograph network, which is operated by the National Research Institute of Astronomy and Geophysics. Earthquakes of this sequence of M (1.5, which occurred during the period from December 1981 to the end of 1995, are classified into shallow- (depth ‹ 10 km) and deep- (10 (depth (30 km) earthquakes in order to carry out the present application of the seismolap method on three data sets (i.e., all-, shallow- and deep-seismic sets). The Gulf of Aqaba earthquake catalogue during the period from 1981 to 1995 is obtained from the Geophysical Institute of Israel. The applied method quantifies the seismic quiescence using the space-time variations of microseismicity. Results of the present experiment demonstrate that the Kalabsha fault zone shows seismic quiescence for M (3.4 earthquakes. The pronounced anomaly of Kalabsha sequence extends over a nearly one year duration and is existed in all the three data sets. It is also characterized by a smooth and sharp amplitude with the deep earthquake sequence in contrast to, its amplitude is of gradually-fluctuated pattern with the shallow earthquake sequence. The most interested feature of Kalabsha seismicity is that a group of significant earthquakes not only a single significant event tends to succeed each quiescence anomaly. In contrast, the present application on the Gulf of Aqaba sequence shows a single quiescence anomaly of about one and half year duration of the seismolap value (S3) before the occurrence of August 3, 1993 earthquake (M = 5.8). It is characterized by a very sharp decreasing amplitude and demonstrates a good example for the seismic quiescence precursor. The above mentioned anomalies of Aswan and Gulf of Aqaba seismic activities are obtained by using values of the method(s free parameters as 730 and 800 days, 50 and 100 km of the time and space window, respectively. A threshold earthquake magnitude of 2 is determined with the both sequences.

Key words: Earthquake catalogue, seismic-quiescence and seismolap method.

A MODEL OF EARTHQUAKE SEEN BY ELECTROMAGNETIC OBSERVATION—GASEOUS EMISSION FROM THE EARTH AS MAIN SOURCE OF PRE-SEISMIC ELECTROMAGNETIC PRECURSOR AND TRIGGER OF FOLLOWED EARTHQUAKE

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Through observation of anomaly in environmental electromagnetic-wave (EM) radiation at ELF band of 223Hz, we have learned that the precursor of volcanic activity and earthquake might be owed to degassing from the earth crust. (1) Intermittent sharp radiation of vertical magnetic flux is estimated degassing process that uplifts pore to pore from shelf to reservoir rock. (2) Burst-like horizontal flux radiation owes to gaseous leakage from the surface and often ended to volcanic swarm at Cape Shiofuki,Itoh-city,Central Japan. (3) Slow creeping variation of vertical magnetic flux was estimated gaseous intrusion between sedimentary rock and shelf, and followed by small and shallow earthquakes of M2.7-3.7 within one week at Usami, Itoh-city. (4) Dynamical movement of the radiation area along Sagami trough valley of the recent Odawara earthquake was caught by direction finding of received anomalous signal. (5) Sub-second change in intermittent radiation, quick area transferability and radiation from sea surface indicate gas-phase. (6) At the instance touch to the air the reducing gas is quickly oxidized and produces neutralized current for radiation. (7) Pressure exerted by gaseous movement produces conductivity variation and resulting earth current change. (8) The degassing makes rock fracture widen, weaken and covered with clay and might end to trigger fault slipping.

SEISMOGRAVITATIONAL PULSATIONS AS POSSIBLE PRECURSORY PHENOMENON

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Phenomenon of the sharp increasing of the amplitude of the Earth's seismogravitational oscillations (period range 0.5–5 hours) with duration of 5–20 hours was called the Seismogravitational Pulsations (SGP). These phenomena is observed several days before strong earthquakes (magnitude $\geq$ 6.5). The relationship between the SGP and earthquake center process have been revealed. Generally SGP, observed in St.Petersburg (Russia), preceded the earthquakes around Eurasian mainland. The SGP preceded the very destroying earthquake near Sakhalin Island (May, 27, 1995). The azimuth of the SGP full horizontal vector and direction from observation point towards the epicenter of the earthquake are the same.
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THE GEOCHEMICAL VARIATIONS CONNECTED WITH THE SPITAK EARTHQUAKE, ARMENIA

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The following geochemical variations in mineral waters of Armenia were revealed before and after the Spitak earthquake.
1. The annual cycles of dissolved helium with a maximum value in summer and a minimum value in winter had disappeared two years before the earthquake.
2. Approximately two years before the earthquake the geochemical precursor, that we called as "geochemical quiescence" was found. To the moment of the main shock the dispersion of macrocomponent mean contents (HCO3, Cl, SO4, Na, Ca) and pH have decreased, while the monthly mean contents remained stable up.
3. Approximately forty days before the earthquake in gas composition the helium precursor variation, that we called as "phase transformation" was settled. Several periods of the spontaneous helium increase together with the decrease of dissolved one and vice versa with the average content of helium remaining almost unchanged were stated.
4. Two days before the main shock the helium daily variations had disappeared.
5. Immediately after the main shock mean contents of a majority of macrocomponents and helium had decreased, while the dispersion became greater.

THE SURVEY OF ANTROPOGENIC AND GEOPHYSICAL ELECTROMAGNETIC PERTURBATION BY USE THE MICRO SATELLITE INTEGRATED IN THE ISS INFRASTRUCTURE.

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The main goal of the scientific experiment onboard the electromagnetic clean micro-satellite (EMCS) and ISS station is to study the electromagnetic disturbances in the ionosphere due to anthropogenic activities and natural geophysical phenomena, particualy earthquakes and volcanic eruptions. Most of previous experiments have been performed at heights above 800 km. The EMCS satellite provides the unique oppotunity to carry out regular observations at much lower heights, about 400 km, in the F-layer. In order to reduce influences of the EMCS on the ambient environment its power consumption is limited to 25-30 W and the onboard systems of the ISS are partly used for the data acquisition and transmission.

Anomalous Preseismic Strain and Tilt preceding Earthquake Swarm off Izu Peninsula in Japan.— Result observed by Multi-component Borehole Instruments

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Earthquake swarm happened off Izu peninsula about 60 km southwest of Tokyo in Japan from March 3rd 1997. The total number of earthquakes reached to more than 10,000. The maximum earthquake was magnitude 5.7 and the activities continued about two weeks. Our Izu borehole observation station is located almost above the earthquake swarm source region and have a muti-component borehole instrument that can record 3 components of strain, two components of tilt, 3 components of acceleration, temperature eqipping with gyro installed in 150m depth borehole. The instrument recorded anomalous variations of both strain and tilt prior to the begining of the earthquake swarm and an earthquake with magnitude 5.0. The precursory tilt started half a day before the begining of the swarm activity. The variation is related to tectonic stress of northeast to southwest tension applied to this region. The coseismic variation reached to 5x10**-5 for both strain and tilt ,and the data indicated strain extension and tilt down. The detailed analysis will be reported in comparison with other observation. We will also demonstrate a comparison with other seismic swarms occuring in this area in different period.

COMPARATIVE ANALYSIS OF TECHNIQUES USED FOR EARTHQUAKE ELECTROMAGNETIC PRECURSORS STUDY

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The existence of electromagnetic (EM) precursors of geological hazards is widely accepted now. Obviously, there are many problems connected both with the diversity of such precursors in dependence on the local geological structure and their low level in comparison with the surrounding EM noises and interference. All these factors make the reliable extraction of corresponding precursors rather difficult. Up to now if do not consider some controversial communications these precursors are observed mainly after the event, processing the observation data. The aim of present study is the comparison of different methodologies of ground based EM measurements and data processing for the extraction of earthquake precursors. Many works are known devoted to different types of electromagnetic precursors study and because their relationship to the seismic activity is highly dependent on local crust structure it is difficult to propose the reliability criterion from all these methods. That is why for the moment only following methods are analyzed: tectonomagnetic survey, EM emission study and extremely low frequency (ELF) active sounding. The expected signal - to - noise ratios and convenience of experimental realization are the comparison base. It is shown the advantages of the last method - ELF active sounding - from every point of view and corresponding calculations are presented.

SIGNALS OF SYNCHRONIZATION AS PROBABLE PRECURSORS OF STRONG EARTHQUAKES.

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It is widely known that increasing of collective behavior of constitutive parts of some system and enlarging of spatial radius of fluctuations of its parameters could be regarded as an important precursor of oncoming catastrophe, abrupt change of system's parameters values. From that point of view detection of signal of synchronization of various geophysical parameters, measured in points of some network, covering a rather big area of Earth crust, is of considerable interest for searching new precursors of geocatastrophes, including strong earthquakes.

A methodics for detection of a signal of synchronization in multidimensional time series data flow is presenting. It is based on estimating of response functions, eigenvalues of spectral matrices and canonical coherences in moving time windows and extracting aggregated signals (such scalar signal, which accumulates in its own variations only those spectral components, which are presented simultaneously in each scalar time series).

Examples of using this technique to processing of real geophysical time series are presented.

CASCADE EARTHQUAKES IN ALBANIA

Abstract

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A complex web of active faults is distributed throughout all the territory of Albania. The intersection of the northwest-trending Adriatic and Ionian longitudinal fault system and northeast-trending shear fault systems, dominates Albanian tectonics and gives rise to recent seismic activity backed mostly by the confrontation between Adria microplate and Albanian orogen.

Sometimes, activation of some active fault produces the earthquake activity in a neighbour one and this process could continue as a cascade through other faults. This may cause the migration of seismic activity from one system of faults to another and sometimes could lead to wrong deduction about the proper fault responsible for an earthquake.

Based on the available data from the records of Albanian Seismological Network, since 1976, some cases of the so-called cascade earthquakes for Albania are evidenced in this approach trying to explain also their mechanism.

Structure functions in geophysical flows

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Extended self-similarity (ESS) (Benzi et al. 1995) is used to analyse laboratory and field data of grid generated turbulence and surface wave generated turbulence. The experiments use velocity point measurements obteined from sonic velocimeter SONTEK3-D, Hot-Film or 2D-electromagnetic current meters measured in the surf zone.

We obtain good scaling at moderate Reynolds numbers using the relative scaling exponents $\bar{\zeta}_p = \frac{\zeta_p}{\zeta_3}$ up to 6th order, some experiments show that the exponents are the same and they do not depend on the Reynolsd numbers *Re*, they are also different from the scaling $p/3$ of Kolmogorov's theory (K41).

We use the Babiano-Dubrulle-Frick model (1997) for nonhomogeneous and nonstationary turbulence, using ESS, to measure the relative scaling exponents even in nonhomogeneous flow. The turbulence is not uniformly distributed in the flow, there are regions with more intense turbulence, more intermittent, and regions with less intermittency, these may be identified by the values of $\bar{\zeta}_p$.

A. Babiano, B. Dubrulle. and P. Frick, 1997. Some properties of two-dimensional inverse energy cascade dynamics. Phys. Rev. E. 55(3): 2693-2706.

R. Benzi, S. Ciliberto, C. Baudet, G. R. Chavarria, 1995. On the scaling of three-dimentional homogeneous and isotropic turbulence, Physica D., 80: 385-398.

PARAMETRIC SEISMOGEOACOUSTIC MONITORING OF SEISMOTECTONIC PROCESSES AND EARTHQUAKE PREDICTION IN THE UKRAINIAN TRANSCARPATHIANS.

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Spatial-temporal monitoring of nonlinear-elastic and parametric tensoeffects in rocks have been used for long for seismoprognostic investigations in the Ukrainian Transcarpathians; it is an efficient indicator of the rock stressed-strained state variations. Combinations of techniques for point investigation held at the network of points and vibrosoundings makes it possible to detect regions of stimulated seismotectonic processes and registrate direst seismogeoacoustic precursors of local earthquakes (creep movements, tensovariational anomalies and "storms"). Complex interpretation of the data obtained, as well as the data based on other geophysical techniques provide monitoring of earthquake preparation, determination of a scenario, interpretation of mechanisms and, thus, determination of seismic danger.

CRUSTAL DEFORMATION STUDY OF JAPAN BY UTILIZING GSI'S DENSE GPS ARRAY.

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Geographical Survey Institute (GSI) of Japan has been constructing its nationwide permanent GPS array since 1994. Its results on crustal velocity field shows that Japan is located on plate boundary region; the north-east Japan belongs to the Okhotsuk plate, and the south-west Japan does to the Eurasian plate. Moreover, the velocity field suggests that Japan consists of several tectonic blocks. Miyazaki et al. (1996) reported an inversion study for a kinematic block-fault model of the Japanese Islands based on a velocity field obtained by 120 GPS sites of the Geographical Survey Institute. After their study, the number of the GSI's GPS stations increased to 610 from April, 1996. Yarai et al. (1997) performed the same inversion study but modified the model of Miyazaki et al. (1996) using dense GPS data from April, 1996 to March, 1997. In this study, we estimate seismic moment and occurence periods of large earthquakes by assuming that magnitudes of future earthquakes will be the average of historical earthquakes. Our results, for example, suggest that the occurence periods on Nankai Trough is 80 - 120 years, and that in the eastern margin of the Japan Sea is about 200 - 400 years.

Radon-exhalation dynamics for predicting tectonic earthquakes

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Radon exhalation in deep mines has previously been found to show the following zonal distribution before mine burts: A radon decrease by factor of 3 to 4 in a zone of compression in the vicinity of the burst and a radon increase by a factor of 8 to 10 in zone of extention at larger distances. A burst event usually occur shortly after the maximum radon change. In the present study we have checked whether a unique set of soil-air radon-concentration data recorded on San-Andreas fault in Caifornia (Chi-Yu King) show similar patterns. Our result shows similar zones of compression (radon decrease), extension (radon increase), and no change for 25 tectonic earthquakes of magnitude 4 and 5, which are always located subsequently in a zone compression. The zone of compression has a dimension of about 25 km for an earthquake of magnitude 4, and 50 km for magnitude 5. The zones of extention usually have a dimension of more than 100 km. The radon values usually begin to show significant changes less then 3 to 4 months before the corresponding seismic events, with maximum changes occurring about 1 to 2 weeks before the events. However such a pattern may be disturbed by the occurrence of forshockes, which may cause additional radon changes. The dynamics of radon exhalation, if properly monitored and analyzed, may be useful for predicting earthquakes.

A TIME CLUSTERING OF STRONG EARTHQUAKES IN GREECE DURING OCTOBER-NOVEMBER 1997

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During October-November 1997 an anomalously high seismicity rate was observed in Greece and adjacent regions with seven main shocks of M_s ranging from 5.1 to 6.6. By adopting the random distribution we prove that the high seismicity episode cannot be attributed to the chance. The calculation of the potential stress-drop stored in each region before the respective earthquake occurrence indicates that all the ruptured regions were prestrained near to failure. On the basis of these results we assume that a geophysical mechanism of triggering earthquakes by earthquakes should be responsible for the strong time clustering. Transient stress changes caused by the triggering earthquakes may play a predominant role in the initiation of the triggered earthquake in a prestrained near to failure region.

PHENOMENA OF LEAP-TYPE ALTERATIONS REVEALED BY SLOPE SOUNDING OF IONOSPHER

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Long term investigations of ionosphere by slope sounding revealed the regularities of alteration of the ionosphere condition in seismogenious zones. Since 1992, in NSSP observations are conducting by radio routes Norway - Yerevan, Liberia - Yerevan, Reunion - Yerevan and Japan - Yerevan of the phase radio navigation system "Omega". Phenomena of appearance of discrete power levels in system Earth - ionosphere in the process of earthquakes preparation has been discovered and is under investigation now. Phenomena displays as leaps of a delay function of radiowaves transmitted from great distance. Such behavior of the delay function can be explained by discrete power levels of energy eradiating by Earth crust in the seismogenious zones.

SUCCESSFUL PREDICTION OF THE LARGE 18 NOVEMBER 1997 IONIAN SEA EARTHQUAKE

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The M_s=6.6 earthquake of 18 November 1997 that ruptured the Ionian Sea to the south of Zakynthos Island concluded the strong earthquake clustering observed in Greece during October-November 1997. A successful prediction was issued before the large shock on the basis of the seismicity synchronization between the Corinthos Gulf (CG) and Ionian Sea (IS) segments. It was observed that during the instrumental era more than 20 shocks of $M_s \geq 5.2$ in CG were systematically followed by corresponding IS shocks of M_s=5.0-6.5 with a time lag up to three months. When the M_s=5.4 shock of 5 November 1997 occurred an earthquake prediction statement was issued which reads as follows: "a strong earthquake of M_s=5.8±0.7 should be anticipated in the Ionian Isl. within the next three months from 5 November 1997 with a probability of about 80%. The area of the next earthquake is defined as 37.2°-38.8°N, 20.0°-21.7°E". A mechanism of earthquake triggering is discussed in terms of transient strain changes propagating from the area of the triggering earthquake to the area of the triggered one.

THE NEW CONCEPTION OF EARTHQUAKES PREDICTION

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The last strong unpredicted earthquakes at US, Japan and Italy, in most advanced technologically and equipped countries, have shown that traditional methods of seismic prediction sometimes fail. During the last decade a lot of papers concerning the electromagnetic and plasma precursors registered at the ground level and onboard the artificial satellites were reported but they were not supported by physical explanation, and therefore, were encountered with great skepticism and opposition, especially from the side of traditional seismologists. In the present paper the concise approach is presented, based on physical foundation, supported by experimental results and corresponding estimations, which, it seems, could be followed by success in prediction of earthquakes in the case of its implementation. The proposed mechanism includes: radon and aerosols emanation from the crust, ionization of gases and aerosols by radon, space charge formation and generation of strong electric field ("1000 V/m) over the anticipated earthquake area, mapping of the near ground vertical electric field into horizontal electric field in the ionosphere, Joule heating, acoustic gravity waves generation, plasma irregularities formation. Every step of proposed chain of physical processes is supported by theoretical estimations and they are consistent with existing experimental results. It is proposed construction of the new global system of seismic warning, including as ground based, so satellite measurements. It could be easily implemented into existing seismic monitoring network, but its main advantage in comparison with traditional methods, that it is able to answer on question "when?", what is inaccessible in present.

SEISMIC HAZARD MONITORING WITH CRETE: *C*RETE *RE*GIONAL *T*ECTONIC *E*XPERIMENT.

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Intense seismicity in this area and complex geodynamic motions with high rates of deformation make Crete -located in the forearc of the Hellenic subduction zone- a suitable physical laboratory for seismic risk evaluation. A base station for the CRETE array has been in operation for several months now and relative positions of sites from previous GPS campaigns have been determined relative to it. A second permanent site is collocated with the tide-gauge at the Naval Base of Souda, near Chania, monitoring local vertical motions and sea-level variations to verify the uplift rates inferred and reported by Lambeck. There is a plethora of competing underlying lithosphere and driving mechanism models to be validated through observations. Inferences from the analysis of earthquake focal mechanisms and assumed spreading vectors at mid-oceanic ridges suffer from the unavoidable assumption of rigid plate tectonics, a rarely valid assumption. High seismicity areas as Crete, exhibit complex local motions beyond the dominant thrusting plate rate. Detailed characterization of such complex deformation requires a dense local network: either a permanent continuously operating one, or one re-occupied at regular intervals. Continuity improves reliability and allows monitoring of the motion without any assumption about its nature. 3-D deformation monitoring has also gained importance since uplift contaminates tide-gauge-determined sea-level variation signals -- of great interest in studying the sea-level change record for eastern Mediterranean.

LOCAL SIGNS OF EARTHQUAKE PREPARING AND ITS AVAILABILITIES.

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It is discussed some valid signs of the earthquake preparing for seismoactive region. These signs are connected with the critical stress state of the earth crust just before the earthquakes. They constitute the subset of observed parameters and they may be considered as short-term earthquake precurcors. It is proposed to use as such parameters: the faint modifications of the seismic signal before earthquakes; variations of the infrared radiation of the rock massif, the variations of electromagnetic fields, etc. The variability of these parameter are depended on the regional characteristics (features of the environment, structure of the earth crust, the oscillator size). Thus this subset may be unique for each region. The second subset consists of parameters which have to be calculated at every point in time (astrometric data, the Earth-Moon system state, etc). They may increase an earthquake possibility.

THE SOFTWARE SYSTEM FOR THE EARTHQUAKE PRECURCOR DETECTION BASED ON THE REGIONAL MONITORING.

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It is discussed the structure of the real-time software system for monitoring, processing and analysis data for the detection short-term earthquake precurcors. The system have to include the data bases with regional data, set of the real time data processing methods for each parameter, the weight estimation algorithms for the parameters of the given region, the algorithms for the learning and the making decision subsystems. The parameters are divided in two subsets. The first one is the parametr set connected with the earth crust critical state (the seismic signal, the infrared radiation of the rock, the variations of electromagnetig fields, etc). All parameters are treated as one multi-dimentional value described the earth crust stress state. The signal-noise ratio is negligible for every parameter. In these cases more efficient may be using the artificial intelligence methods (the pattern recognition, linguistic, fuzzy logic, neuron networks, etc). The second subset consists of parameters (astrometric data ,etc) which may increase an earthquake possibility at this point in time.

ANANLYSIS OF ICELANDIC EARTHQUAKE PRECURSORS IN THE PRENLAB PROJECT

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Premonitory activity before earthquakes has frequently been observed in Iceland, both instrumentally and historically. Such activity, especially seismic, can be devided into 3 main categories. 1) Foreshocks, i.e. small earthquakes observed hours or days before a larger earthquake. 2) Intense sequence of earthquakes, lasting for days or weeks preceding a larger earthquake, where the preceding sequence has a moment comparable with the main earthquake. 3) A large earthquake of magnitude of about 7 precedes somewhat smaller but catastrophic earthquakes in nearby areas within weeks. Besides these types of premonitory changes it has frequently been observed in history that large events, earthquakes and volcanic eruptions, coincide in time over areas of the order of several hundred kilometers. This has been called strain waves. Besides the seismic premonitory changes comparable observations have been made of radon, volumetric strain, and shear wave splitting changes. Tentative models will be demonstrated for explaining the above mentioned observations.

TEMPORAL VARIATIONS OF THE ATMOSPHERIC ELECTRIC FIELD AS AN EARTHQUAKE PRECURSOR

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Many investigators of the atmospheric electricity observed anomalies in the atmospheric field behaviour before and during some strong earthquakes. The observation results were contradictory because of imperfect and variegated instruments. Special sensitive equipment was developed and used for comparatively long measurements of the electric field strength of the atmosphere in seismically active regions of the Pamirs and Tien Shan. All of observations were conducted with identical electric field sensors. The analysis of the results of measurements showed that the quasi-static electric field of atmosphere, as a rule, experiences characteristic variations shortly before earthquakes. In particular, since several (generally 5 - 7) of hours before an earthquake the value of the electric field strength begins to decrease, then the field strength changes its direction to the opposite. The anomaly lasts from 20 minutes to 4 hours, the most likely meanings - from 1 to 1.5 hour. Besides, it was noted that since several days before an earthquake there exist time intervals with comparatively quick variations of electric field with period in the dozens of seconds. The amplitude of these variations and the duration of the intervals of time for which they are seen grow with approach to the earthquake date. The results of investigations allow to consider the specific temporal variations of the atmospheric electric field as a potential earthquake precursor.

'MOVING CHARGED DISLOCATION MODELLING' OF ELECTRICAL EARTHQUAKE PRECURSORS : A PROMISING APPROACH ?

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We present and discuss a model of EEP generation and propagation as a function of the medium and source-receiver separation, based on the concept of *Moving Charged Dislocations (MCD)*. Signals generated by this process are modulated by a source time function featuring a corner frequency and an inverse power, energy distribution law. This allows the generation of a limited class of signals with characteristic bay-like shapes and duration from a few tens of seconds (close ranges/resistive media/fast source functions) to a few hours. We apply this model to analyse a signal which was associated with the 18/11/92, M5.9 Galaxidi event (Greece). We were able to reproduce the observation in shape, using generic parameters of the earthquake source and the MCD model; reproduction in magnitude is possible, but only under untestable as yet considerations. This apparent success suggests that the MCD model may be promising towards establishing a working theory of the EEP source. Moreover, if data from more than one station existed, the procedure could be invertible to source parameters. This concept is discussed in the context of seismic hazard evaluation.

SEISMIC QUIESCENCE IS SIMILAR TO FORE- AND AFTERSHOCKS

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We hypothesize that the seismicity rate is normally constant. Before and after major earthquakes, the seismicity rate in and near the source volume is often disturbed: Fore- and aftershock sequences are the well known expressions of this, but precursory as well as post-quiescences exist. For the post-main shock quiescence the redistribution of stress due to the main event is the obvious cause, as it is for the aftershocks. Although precursory quiescence and foreshocks are clearly defined in many cases, their cause is not obvious. In some cases they may be explained by precursory aseismic creep. Examples of constant seismicity rate are abundant in deep seismic zones. In 70 seismogenic volumes below 60 km depth of 500 earthquakes each in periods of 8 to 30, we found that the standard deviation was close to that expected from a Poisson distribution. Examples of post-quiescence are found on the San Andreas Fault near Parkfield and along the east coast of Japan, where main shocks of M4.7 and M7.5 were followed by complete absence of earthquakes for several years in neighboring volumes that previously produced large numbers of earthquakes. In the same tectonic provinces precursory seismic quiescence of a few years can be clearly defined for some main shocks, the M6 Coyote Lake and Morgan Hills earthquakes along the Calaveras fault, and the M7.1 off-Sanriku earthquake, Japan. Like foreshocks, precursory seismic quiescence is an obvious phenomenon that is however not understood yet.

NH3 Earthquake risk mitigation (co-sponsored by SE)

03 Macroseismics: present state of intensity-assessment procedures and future perspectives

Convener: Tertulliani, A.
Co-Convener: Cecic, I.

A DISTRIBUTION-FREE ANALYSIS OF THE MAGNITUDE-INTENSITY RELATIONSHIPS: AN APPLICATION TO THE MEDITERRANEAN REGION

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A procedure for the statistical analysis of the relations between macroseismic intensity and magnitude is presented. In order to overcome the problem due to the heterogeneous nature of the two quantities involved, intensity and magnitude, relationships have been studied by means of a distribution-free statistical approach. The data-set examined is constituted by earthquakes of epicentral intensity >=VI occurred in the Mediterranean region. As known, magnitude-intensity relations depend on a number of local features (e.g. average hypocentral depth, etc.) but, owing to the nature of the adopted data-base (resulting from the integration of many national and regional seismic catalogues) they can also be affected by the use of different macroseismic and magnitude scales. The role of every variable able to influence the magnitude-intensity relations (i.e. intensity scale, source catalogue and earthquakes location) has been evaluated by means of an opportune correlation analysis (e.g. Cramer correlation coefficient).

SEISMIC HAZARD ESTIMATES FROM FELT INTENSITIES AT THE SITES SHAKEN FROM THE 1997 CENTRAL ITALY EARTHQAUKE

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In order to fully exploit available macroseismic data concerning earthquakes that in last centuries shook central Italy, seismic hazard analysis has been carried out by using non standard statistical techniques. In particular, methodologies developed for the analysis of ill-defined macroseismic data have allowed the combined use of intensity estimates deduced from documentary sources or computed from epicentral data by taking into account the different level of data reliability. Furthermore, the proposed approach also allows the use of the whole seismic history by also taking into account the time varying completeness of the available seismic catalogue. Since the adopted data set concerns a time interval spanning from 1000 A.C. up to 1980, the comparison of seismic effects observed during the last seismic crisis in Central Italy (september-october 1997) with the ones expected on the basis of seismic hazard estimates supplied by standard procedures and by the one here proposed, could allow a check of the relative reliability.

A New Attenuation Law for the 1755.01.11 Lisbon Earthquake

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The 1755.11.01 Lisbon earthquake was felt strongly on Portugal, Spain and Morocco, specially along the Atlantic coasts. The intensity at the epicenter is estimated in XI (MSK) and its magnitude, inferred from macroseismic data, is 8.3/4 (Guttenberg and Richter, 1949). The tsunami magnitude, Mt=Mw, was estimated by Abe (1989) based on the tsunami run up data observed along the Iberian coast. Macroseismic Intensity maps were published for Portugal, Spain and Morocco separately and the corresponding attenuation laws were fitted. Most of these laws are based on the assumption that this event was generated in the same oceanic region and by a similar rupture mechanism that the recent instrumental event that occurred on 19169.02.28. The recent hydrodynamic simulations on the 1755.11.01 Lisbon tsunami showed that the location of the source area and the rupture mechanism are different from the 1969.02.28 event that was located at the Horseshoe Abyssal Plain (North Atlantic), Baptista et al., 1998). In view of these results a new compilation of macroseismic Intensity data was made with data from Portugal, Spain and Morocco and a careful revision of the existent attenuation laws was made. The new attenuation law was fitted using 820 data points and Levenberg Marquardt algorithm.

PROBLEMS OF INTENSITY ASSESSMENT AT LOCALITIES SHAKEN BY DAMAGING EARTHQUAKE SEQUENCES

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The problem of assessing macroseismic intensity at localities affected by several damaging earthquakes during a short time interval is well known. In such cases, usually, after the first strong shaking the buildings vulnerability is lower than before, though it is not easy to assess "how much lower". Therefore, to assess intensity one has to move through the vulnerability table, with little hints. To neglect these aspects lead in the past to unreliable intensity estimates and, from them; to unreliable magnitudes for aftershocks. This paper analyses some cases, with special reference to three major earthquakes (Io = IX, IX and X MCS) which, in 1741, 1747 and 1751 occurred in a comparatively narrow area of the Apenninic region, then belonging to the Papal States, where also the 1997 earthquake took place.
They set in motion the production of huge amounts of official documents (surveys, reports and so on) that give detailed descriptions of damage suffered by single buildings and/or by all buildings in many affected localities. These data provide a "damage record" for many localities of different status and size, from provincial towns such as Fabriano, Nocera Umbra and Gualdo Tadino, to small villages such as Belvedere or Campodonico. Problems of intensity assessement from that record are compared with similar problems encountered when assessing intensity for the recent 1997 sequence.

THE USE OF THE EMS-1992 SCALE IN THE FIELD WORK: EXAMPLES FROM THE CENTRAL ITALY, SEPTEMBER - OCTOBER 1997

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In September and October 1997 the regions of Umbria and Marche in Central Italy were hit by a sequence of strong and damaging earthquakes, with epicentres in the vicinity of towns Nocera Umbra, Colfiorito and Sellano. Few days after the first earthquake an ad-hoc expert team was formed of the seismologists, geologists, historians, architects and geographers who made quick survey of the most devastated area. The macroseismic data were collected in a great extent, in order to be able to use EMS 1992 scale while estimating the intensities. A preliminary field form was constructed and used as a common base for the collecting of data. Several problems were met during the field work and intensity estimation process, due to a lack of experience with EMS on the one side and the huge damaged area that was getting bigger every day on the other. Main problems were how to establish building typology and how to separate damage effects of different shocks. The field experience led us to believe that some improvement in the scale is needed in order to give more indication about building classification and building behavior and resistance after damage. During the field work we discussed a possibility of "inserting" a degree between VI and VII, as in many localities the observed damage was more than VI and less than VII.

MACROSEISMIC SURVEY OF THE CENTRAL APENNINES EARTHQUAKES OF SEPTEMBER-OCTOBER 1997

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After the two first major shocks of September 26, 1997, in the Umbria-Marche area, the National Group for Defence against Earthquakes of Italy's National Council of Research (GNDT/CNR), the National Seismic Survey (SSN) and the National Institute of Geophysics (ING) started a joint macroseismic survey. At first, a preliminary evaluation of the maximum effects and a rough delimitation of the damaged area were effected using data gathered by field investigation and also - due to the extension of the damaged/felt areas - through press and technicians' reports and telephone interviews. From October 3, a more detailed field survey started in the most heavily damaged localities, with the aims of discriminating (whenever possible) the effects produced by each of the main shocks, to test the European Macroseismic Scale EMS-92, and also to record the worsening of damage scenarios, progressively caused by the strongest aftershocks. New stages of the survey were carried out after new damaging aftershocks, on October 8 and from 16 to 19 October, particularly in the areas of Sellano, Preci, Alta Valnerina and Alto Maceratese.
This paper presents the intensity distribution reconstructed up to October 20, with an account of the interpretative problems encountered in the process and of the solutions adopted to deal with them.

MACROSEISMIC INVESTIGATION OF SOME PRE- AND INSTRUMENTAL PERIOD EVENTS FROM THE GULF OF CORINTH

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Despite the existence of ample macroseismic intensity data from pre-instrumental earthquakes, their inherent inconsistencies prevail from using them as input to modern seismic hazard techniques. It has often been stressed in the last decade that the intensities of historical earthquakes should be re-evaluated using the available primary sources and according to the currently used intensity scales. This is also the case for events of the early instrumental period, where the use of different intensity scales has produced inhomogeneous macroseismic intensity data sets. In the present study the intensities of historical, as well as early instrumental earthquakes from the area of the gulf of Corinth, Greece, are re-evaluated, and their distribution is derived. These distributions are calibrated to recent events from the same area, in an attempt for a better evaluation of the size of these events. In addition, and since the focal mechanism of the earthquake is directly related to the observed intensity distribution, the possibility of associating the pre-instrumental events to known faults with known focal mechanisms of recent earthquakes is examined.

THE ZAGREB 1502 EARTHQUAKE - DOUBTFUL OR EVEN FAKE?

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In the BEECD working file, and before that in Balkan catalogue, the earthquake on 26 March 1502 at 13 h has intensity IX MSK. The similar entry can be found in the Croatian earthquake catalogue. Its historical part relies a great deal on Kispatic (1891). The oldest source given by Kispatic for this earthquake was a chronicle written by Joannis Tomasich in 1561: "Anno Domini 152. die 26 Martii hora 2 post meridiem", and the tower of St. Marcus church in Zagreb was destroyed to the fundaments. The year of the event is written in a way that could lead to different interpretations. The Valvasor's famous chronicle also quotes Tomasich as a source for this earthquake, but giving the date 6 March 1502. The damage on the tower is not mentioned in the books of the St. Marcus church (Kispatic, 1879). Also, the annual overview of the Bishop's expenses for the time period 1501-1505 does not show any increase in the sum for the regular maintenance of Zagreb chatedral, which is about 500 m away from St. Marcus. Moreover, king Vladislav II (Wladislaus) allowed the city of Zagreb to use taxes to repair the bad condition of the houses after the recent earthquake; the document was dated in 1511 (Tkalcic, 1896). Although there is still a lot of work for the historians to be done to find more proofs of our hypothesis, we believe that the described effects speak about the event on 26 March 1511 at 14:30, which occured in border region between Slovenia and Italy.

VERIFICATION OF MACROSEISMIC METHODS ON TWO M=5.2 INSTRUMENTAL EARTHQUAKES IN FRANCE.

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Macroseismic data available for the two most recent M=5.2 earthquakes that occured in the Pyrenees and in the Alps, were analyzed using the Sponheuer and the Levret relationship to estimate depth and magnitude respectively. The excellent agreement between macroseismic and instrumental estimates shows that macroseismic data of historical events may provide the means to lengthen the instrumental catalogue and better constrain the recurrence rates of these two low to moderate seismic rate regions.The Epagny earthquake occured on the 07/15/1996 along the Vuache fault in the French Alps. Instrumental and macroseismic depth estimates both indicate a shallow hypocenter location of around 3-4 km. The question raised by this event is whether the Vuache fault, a conspicous NW-SE trending left-lateral strike-slip fault, is a superficial or a crustal feature. Analysis of macroseismic data available for earlier events (1975,1936,1839) indicates a rather superficial fault generating M=5 earthquakes that originate in the first 4-5 km of the crust. The St Paul de Fenouillet earthquake occured on the 02/18/1996. Its depth is around 10 km, presumably on a ramp structure of the North Pyrenean Frontal Thrust. Again, reasonable agreement between instrumental and macroseismic estimates is found and the study of historical events (1920, 1922) provides important information as to the behaviour of the seismic structures in this part of the eastern Pyrenees.

DISTRIBUTION OF EFFECTS IN THE URBAN AREA OF ROME, FOR THE OCTOBER 14, 1997 (CENTRAL ITALY) EVENT

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During the last years many improvement have been done by historical seismologists outlining more and more the response to the seismic shaking of the downtown of Rome, at the occurrence of large earthquakes. Till now, only historical data evaluation were available to check the seismic vulnerability of Rome. The possibility to verify our knowledge on the basis of recent earthquake was the occurrence of the October 14, 1997 event, located in the Central Apennines region (M_W=5.7), which has been largely felt in the city of Rome (far about 115 km). A prompt macroseismic survey in the Roman urban area was performed, to obtain the picture of shaking in the whole city. For this earthquake, we were able to collect macroseismic information related to several hundreds topographic points. It is the first time that such a large amount of data is available for Rome. The analysis of the data points out a preferential distribution of larger effects within Holocene alluvial sediments, but it also allows us to individuate some areas where local amplification phenomena occurred. Such areas are characterised by recent terrain hosting more levels of water-tables.

FROM QUESTIONNAIRES TO INTENSITIES - ASSESSING FREE-FORM MACROSEISMIC DATA IN THE UK

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Questionnaires for macroseismic surveys can generally be categorised into two groups: structured questionnaires, where respondents are given a number of options and have to tick one, and free-form questionnaires, where open-ended questions are answered by the respondents in their own words. Both have advantages and disadvantages. The structured approach is easier for the seismologist to process and is more focussed on the answers he wants to receive. The free-form approach is better at preserving nuances and qualifications to the respondents' answers that might otherwise be lost. Free-form questionnaires can be a lot shorter than structured ones, and it is partly for this reason that practice in the UK since 1974 has been to employ such a questionnaire design; short questionnaires can be distributed widely by being printed in local newspapers. The questionnaires received are then sorted by place, and for each place a synopsis sheet is prepared summarising the reported effects. Intensities are then assigned from the synopsis sheets, with reference back to the questionnaires where necessary. Data are checked using a pseudo-GIS program, and the final maps are prepared with the GMT mapping package.

STRATEGIES FOR THE USE OF MACROSEISMIC INFORMATION IN THE STUDY OF GROUND RESPONSE TO SEISMIC EXCITATION

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Given a magnitude value and an epicentre location what is the intensity to be expected at any selected observation site? Regarding this topic, macroseismic information from Continental Portugal was used to obtain empirical expressions for ground intensity response to seismic excitation. Different approaches were tried and analysed, in order to minimise the uncertainties associated to the corresponding intensity predictions. 1) Fits considering intensity (I) as a function of magnitude (M) and epicentre or focal distance (D), and fits considering I as a function of D for constant M, were obtained. In order to analyse the influence, in regressions results, of the way the input set is selected, given the zone of observation sites and the region of epicentres, different groups of data points were considered in these fits: a) sets with EMS intensity value 1 points, and sets without them; b) sets with different amounts of points of the different intensity values; c) sets with transformed data points, such as points with average distance for given intensity and magnitude, points with hypothetical intensity distributions - intensity considered as varying continuously with distance - for each magnitude and EMS intensity value, and points with the average distances to the isoseismals. 2) I as a function of M fits were computed for data from delimited epicentre areas. Conclusions on the use of these procedures were obtained.

CORRELATION OF SEISMIC INTENSITY WITH FOURIER ACCELERATION SPECTRA

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Many attempts have been made to correlate intensity with ground motion parameters. The correlations with peak amplitudes and duration show great scatter, and till the present there is no equation sufficient enough to determine seismic intensity in terms of physical parameters. We present a method for estimating of seismic intensity in terms of MMI or MCS scale using Fourier amplitude spectra of ground acceleration. The method implies that the severity of earthquake ground motion is determined by spectral amplitudes in relatively narrow frequency band: so-called "responsible frequencies", which decrease (from 7-8 Hz for small intensities to 0.7-1.0 Hz for MMI=VIII-IX) with increasing of the intensity. We examined our model through estimation of prabable intensity using records of recent earthquakes occured in several seismic regions, and prediction of intensity distribution patterns for Coalinga, California earthquake of May 2, 1983, and Spitak, Armenia, earthquake of December 7, 1988. We beleive that seismic hazard maps in terms of intensity scale levels based on the proposed approach would provide a better account for regional features of seismic waves excitation and propagation, as well as for local ground conditions.

INTENSITY VS CATALOGUES: THE CASE OF THE 1975, JUNE 19 GARGANO (SOUTHERN ITALY) EARTHQUAKE

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Italian seismic Catalogues suffer the problem that intensities of many moderate seismic events (historical and/or present), are often derived from intensity-magnitude relationships, or evaluated only from preliminary sources. In those cases intensities are not assessed by macroseismic studies; consequently, it is possible to find contradictions among different Catalogues, as they often follow different way of intensity assignment. As example, the case of the 1975, June 19 earthquake is presented in this poster. This event occurred in the Gargano area (Southern Italy) with a magnitude M_L=5.1 (ING Seismological Bulletin). The corresponding intensity value reported by the ING Catalogue is I = VIII (computed), while the NT4.1 Catalogue quotes I = VI MCS. Moreover the PFG Catalogue reports this earthquake without intensity. The case of this event is emblematic of a period in which macroseismic studies were not undertaken systematically in Italy. The macroseismic intensity of this event is now assessed by the use of the normal procedures implemented at ING.

CROATIAN MACROSEISMIC DATABASE

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The compilation of the digital Croatian Macroseismic Database is an ongoing project that started in 1995. A total of 426 earthquakes is currently being analyzed. The job is carried out through several stages, each of them corresponding to digitalization of a different input data format (isoseismal- and intensity-maps, intensity point lists, questionnaires, etc.) At first, the 69 isoseismal maps published in the Catalogue of Earthquakes in the Balkan Region have been digitized. The coordinates of the intensity points were assigned to geographic locations (villages, cities, ...) by consulting the data base of latitudes and longitudes of all settlements in Croatia. The 330 existing intensity lists (intensity and name of the place without coordinates) were entered into the database during the second step. The isoseismal maps which were not published so far will be scanned and digitized during the third stage of the project. Main problems encountered so far have to do with digitization from the imprecisely drawn intensity maps based on unspecified cartographic projection, in which case we had to employ various methods of coordinate interpolation in order to be able to assign observed intensity to a geographic locality. Once finished, the data-base will offer possibility to analyze many aspects of the macroseismic field in Croatia (intensity attenuation, distribution of the maximum observed intesities, influence of local soil conditions, etc.).

PRELIMINARY RESULTS OF THE MACROSEISMIC SURVEY OF THE COLFIORITO SEQUENCE (CENTRAL ITALY)

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The recent seismic sequence occurred in Umbria-Marche region (Central Italy), starting from September 4, 1997, has caused a large amount of damage in a quite wide area. The sequence produced almost five shocks with magnitude higher than 5.0, the largest of them occurred on September 26, UTC 09 :40, M_l =5.8 . The occurrence of many shocks with magnitude higher than 4.0 has contributed to create a damage pattern "in evolution" for over a month. Such seismic behaviour obliged the operators in the field to perform a real-time macroseismic survey to update the data set. One of the major efforts was to discriminate the effects due to each of the largest shocks. In this work we present the macroseismic survey performed during the sequence and some preliminary result inferred from it. The intensity points and macroseismic fields related to the largest quakes of the sequence are presented. Finally some consideration drawn by comparison with instrumental and geological data are shown.

TESTING THE EUROPEAN MACROSEISMIC SCALE IN THE CASE OF THE 1997, CENTRAL ITALY EARTHQUAKES

Working Group on EMS data of the 1997, Central Italy earthquakes. Reference person: M. Stucchi*
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Damage caused by the 1997, September and October, Central Italy earthquakes was investigated by making use of both MCS and EM intensity scales. Data collected in the view of this test are available for about 70 localities of the most damaged area. These data will be compared against damage data collected by engineers for safety purposes.
The main problems of the survey came from the sequence of damaging events which took place in about three weeks. This situation requested quick, repetitive and therefore not exhaustive investigation, the limits of which are discussed here. The comparison between the intensity values assessed according to the two scales shows interesting insights.

A FUZZY SYSTEM TO ASSESS SEISMIC INTENSITY

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We show a technique which allows the encoding and the computer processing of macroseismic effects in order to keep trace of all the steps in the intensity assessment process. It makes use of a multi-criteria decision making algorithm based on the Fuzzy Sets Theory (FST). For two italian earthquakes (the 1919, Mugello and 1920, Garfagnana) we exhaustively classified all the earthquake-related effects found in the available sources, without referring to any macroseismic scale. This classification is based on the decomposition into elementary syntactic components, of any meaningful sentence which can be associated to a set of 5 alphanumerical codes. This method grants the highest adherence of the recorded data with respect to the source contents, since it avoid forced interpretation and the loss of all the information that do not fit into scale descriptions. The availability of the information on computer media allows the reorganization of the data-set in order to group effects which where previously kept distinct but are thought to be equivalent in further processing. The extension of the data-base to a sufficiently large number of earthquakes could allow the definition of a new macroseismic scale on a purely statistical basis.

REVISED MAGNITUDES OF HISTORICAL EARTHQUAKES IN SLOVENIA

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For statistical estimation of earthquake hazard it is of large importance to have unified measure of earthquake size. For historical events no instrumental data are available. Consequently a link between intensity and magnitude is needed. Epicentral or maximum intensity is usually poorly correlated with magnitude, so magnitude formulas based on isoseismal radii are derived. For 18 earthquakes in Slovenia there was isoseismal map available as well as M_{LH} magnitude. Isoseismals were digitized and the relation between magnitude M_{LH} and equivalent radii R of isoseismals were derived:

$$M_{LH} = 2.72 + 1.63 \log R_{VI} \ (r^2=0.68)$$
$$M_{LH} = 1.08 + 2.32 \log R_{V} \ (r^2=0.67)$$
$$M_{LH} = 1.14 + 1.96 \log R_{IV} \ (r^2=0.71)$$

Magnitudes were determined for the events for which isoseismal radii for intensities IV, V and VI were available in the catalogue. The reason for choosing these values was because in 20th century there are not enough data for intensites VIII or VII, which could be used to calibrate magnitude formulas. The strongest earthquake in 20th century was of M_{LH} = 5.7. Revised macroseismic magnitudes for the two strongest events in Slovenia are:

26.03.1511. M_M=6.8 ± 0.3
14.04.1895. M_M=6.1 ± 0.2

NH3 Earthquake risk mitigation (co-sponsored by SE)

04 Active fault and earthquake risk mitigation

Convener: Barka, A.A.
Co-Convener: Stewart, I.S.

EARTHQUAKE SURFACE FAULTING IN VOLCANIC AREAS: A CASE-STUDY FROM MOUNT ETNA (SICILY)

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Coseismic faulting is generally associated with moderate-large earthquakes (M> 6.2) with extended overall lengths (tens of km) and relevant offsets (in meters). Occasionally ground rupture occurs also with very shallow, low magnitude events (M<4.5) because of peculiar tectonic conditions, for example in active volcanic zones. The present study has allowed the recognition of surface ruptures for a large number of earthquakes occurring at Mt. Etna since 1818 to date by means of a careful search and re-examination of historical sources and recent data. Analysis of surface faulting provided not only a clearer relationship between seismicity and mapped structures to emerge but also a better definition of the volcano's tectonic framework through the identification of previously undetected, long hidden faults. Critical interpretation of data and ad hoc field investigations allowed also to verify behaviour (kinematics, slip per event, length of rupture) and geometry of seismogenic segments. These findings provide not only effective evidence of ongoing tectonics but also useful elements for seismic risk mitigation. In fact, surface faulting in a densely urbanised area such as the Etnean one is a singular and overlooked source of hazard, destroying houses astride the ground rupture or interrupting essential lifelines (tollway, railway, methane pipeline, etc.).

FAULT KINEMATICS AND EARTHQUAKE RISK: CHIHSHANG, TAIWAN

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In eastern Taiwan, across the active boundary between Eurasia-Philippine Sea plate, the fault slip was studied during the period 1982-1997 on the Chihshang Fault, a segment of the Longitudinal Valley Fault known active for the last 30 years.
Four sites allowed quantification of fault offsets, because massive buried concrete walls reliably recorded ground deformation. Displacements vectors were measured yearly (1990-1997), in terms of both the amplitudes and the orientations.
At the longest survey site, the total shortening is 29.2 cm in about 11 years. For all sites, the average velocity is 2.4 cm/yr, about one third of the total shortening across the whole Taiwan orogen. Motion vectors trend N120-155°E while the fault strikes N23°E, indicating thrusting with left-lateral component.
The increase in total shortening was nearly linear during the period 1986-1997. After the large 1951 earthquake sequence, creep dominated across this major fault. Minor velocity variations occurred, but no significant decrease in velocity, which would have indicated compressional stress accumulation and increasing seismic risk along the Chihshang Fault, was identified between 1982 and 1991.
Quantitative studies carried out at the outcrop scale along active faults have the potential to allow detection of a decrease in local aseismic slip velocity. Such phenomenon may reflect accumulation of compressional strain across a nearby zone, hence increasing earthquake risk, for the overall deformation is continuing across the seismically active convergent boundary (see Angelier *et al.*, this meeting).

COULOMB MODELING OF MARMARA SEA EARTHQUAKES SINCE 1700: IMPLICATIONS ON THE EARTHQUAKE HAZARD OF THE ISTANBUL REGION

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Present-day failure stress distribution of destructive earthquakes (I≥VIII, M≥6.3) occurring since 1700 along strands of the North Anatolian fault in the Marmara Sea region is calculated from Coulomb modeling. This is important in particular for the City of Istanbul which is the center of high population (10 Million) and economy. Our investigation is mostly concentrates on the NE-SW trending central Marmara Sea ridge which represents one of the major strike-slip segements. From the historical earthquake records we beleived that the last large earthquake on this ridge was the 1509 earthquake (I=IX-X). GPS measurements illustrated that the slip rate along the northern strand of the North Anatolian fault is more than 10 mm/yr. Our results from the failure stress modeling indicated that the 18th century earthquakes caused stress increase on this ridge, however, this segment was not ready to rupture at that time. If we consider the GPS rate, at present there has been approximately 5 m slip allready accumulated on this segment since the 1509 earthquake. Furthermore, our modeling predicts that this strike-slip segment is most likely to be triggered, if there is a moderate normal fault earthquake in the basins which are bound to this ridge from the east and west.

SEISMIC HAZARD IN THE CAUCASUS REGION

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This study involves the determination of the earthquake hazard in the Caucasus region in probabilistic terms. The area considered is identified as one of the test sites of Global Seismic Hazard Assessment Program (GSHAP). The prominent features of the study are rational delineation of source zones based on different neo-tectonic maps and regionally seismicity; utilisation of spectral amplitude attenuation relationships and; the use of GIS technology in the treatment of data. The neo-tectonic regime and the historical seismicity of the region Several neo-tectonic fault maps and historical seismicity catalogues of the region were guiding tools in the delineation of the following seismic source zones: North Anatolian; Bitlis-Zagros; Black Sea; Pambak-Sevan; Greater Caucasus; Tabriz; Talish; Soltanieh-South Parandak and Arax. The variability of the available neo-tectonic maps introduced uncertainties in some of the source boundaries. For the probabilistic hazard analysis the Poisson model is retained on account of its simplicity, its adequacy for large magnitude events and the fact that the seismic design decisions should be more sensitive to the mean number of events than to their temporal distribution. A sensitivity analysis conducted to assess the influence of the variability of the source boundaries. The earthquake hazard is quantified as contours of iso-peak ground acceleration and iso-spectral acceleration corresponding to different return periods. The results are compared with other studies conducted for the same test area using deterministic, historical-probabilistic and areal-probabilistic techniques.

SEISMIC HAZARD IN THE CAUCASUS REGION

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This study involves the determination of the earthquake hazard in the Caucasus region in probabilistic terms. The area considered is identified as one of the test sites of Global Seismic Hazard Assessment Program (GSHAP). The prominent features of the study are rational delineation of source zones based on different neo-tectonic maps and regionally seismicity; utilisation of spectral amplitude attenuation relationships and; the use of GIS technology in the treatment of data. The neo-tectonic regime and the historical seismicity of the region Several neo-tectonic fault maps and historical seismicity catalogues of the region were guiding tools in the delineation of the following seismic source zones: North Anatolian; Bitlis-Zagros; Black Sea; Pambak-Sevan; Greater Caucasus; Tabriz; Talish; Soltanieh-South Parandak and Arax. The variability of the available neo-tectonic maps introduced uncertainties in some of the source boundaries. For the probabilistic hazard analysis the Poisson model is retained on account of its simplicity, its adequacy for large magnitude events and the fact that the seismic design decisions should be more sensitive to the mean number of events than to their temporal distribution. A sensitivity analysis conducted to assess the influence of the variability of the source boundaries. The earthquake hazard is quantified as contours of iso-peak ground acceleration and iso-spectral acceleration corresponding to different return periods. The results are compared with other studies conducted for the same test area using deterministic, historical-probabilistic and areal-probabilistic techniques.

DEFINING SEISMOGENIC SOURCES FROM HISTORICAL EARTHQUAKE FELT REPORTS

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We present a method to assess the location, physical dimensions and orientation of the source of large historical earthquakes that relies entirely on intensity data. Seismological theory and practice show that the orientation of the seismic source of earthquakes larger than $M \geq 5.5$ is reflected in the elongation of the associated damage pattern. A physically plausible and easily understandable way of describing a seismic source is by representing it as a properly oriented "rectangle", whose length and width are obtained from moment magnitude through empirical relations. This rectangle is meant to represent either the actual surface projection of the seismogenic fault or, at least, the projection of the portion of the Earth crust where a given seismic source is more likely to be located. The systematic application of this method to all the $M \geq 5.5$ earthquakes that occurred in the central and southern Apennines (Southern Italy) in the past four centuries returned encouraging results that compare well with existing instrumental, direct geological and geodynamic evidence. The method is quite stable for different choices of the algorithm parameters and provides elongation directions which in most cases can be shown to be statistically significant.

SEISMIC HAZARD AND SEISMIC RISK ASSESSMENT FOR SOCHI CITY

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According to the temporary map (scale 1:1 000 000) of seismic zonation of the Northern Caucasian territory, adopted by the Ministry of Construction of Russian Federation in 1994 as a standart, Sochi , the Black Sea shore of Russia, is located in a zone of expected intensity IX on the MSK scale, with average recurrence of such earthquakes once per 1000 years within the area of one thousand sq.km. In comparison with the previous standart map of seismic zonation of the former USSR, the city seismicity was increased by 2 grades of intensity scale. In order to verify the seismic hazard level the schematic map (scale 1: 100 000) of tectonic faults was compilied with the use of space photography. As 30% of the mountain area of the city is exposed to landslides, mudflows, avalanches, the detailed engineering geological study was carried out. Seismic risk (ecomonic and social losses) was computed with taking into account the verified seismic hazard level and other geological processes. The corresponding maps of total direct losses caused by damage to residential buildings from scenario earthquake, summary direct losses taking into account secondary technogenous processes, as well as of specific social losses (number of people killed and injured per unit square) were compiled on the scale 1:50 000. The obtained results allowed to estimate the insurance rates for Sochi City.

NON-TRADITIONAL ASPECTS OF SEISMIC HAZARD IN THE ZONE OF ACTIVE FAULTS WITHIN THE RUSSIAN PLATE

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Study of spatial migration of earthquake epicentres with M>3.0 for a phase 1963-1992 years has shown that seismoactive faults of Fennoscandia extend to Russian plate. Tectonic zones of the Baltic Shield and Northern part of the Russian plate create a complicated pattern in space and a combination of faults, grabens, horst, forming a peculiar tectonic framework of structures successively evolving in time represent. These zones are characterized by inheritance in space, re-iteration and association with weakened zones of general NW and NE direction from Late Archean to present. The epicentres of earthquake form the belt extending in NE and NW directions. These direction conform with faults dividing Baltic Shield and Russian Plate into separate tectonic bloks.The investigations carried out by the authors, has shown, that in Archangelsk's region these structures are ruinous for marine stars in Onega and Dvina Gulfs, fishes in Lekshmozero. The main causes of the phenomena of earthquakes influence on the environment are not clear. Some of causes are: horizontal and vertical migration of the geochemical elements, the fluides of depth gases, fluctuations of electro-magnetic fields and contamination by toxic organic matter, is intrinsic in basement and sedimentary rocks of the Russian Plate, in the zones of seismoactive faults. The main stream of gas is moving through the faults and by the zones of fracture. The important role in this process the recent tectonic movements and migration of earthquake epicentres play.

PROGRAM OF THE NUCLEAR POWER STATIONS SEISMIC PROTECTION IN THE UKRAINE

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The seismic situation in the Ukraine is considered as calm in general. However, it territory contains the seismic active M 6-7 with the local sections M 8 zones. There are Crimea zone, Carpathy, all south-west part of Ukraine, seismic active zones of the East-European platform boundary, Donbass. The large industrial units, in particular, the nuclear power stations (NPS) have been built there and in other seismic active regions. Ukrainian NPS are usually situated near large cities and it damages could cause the essential economic disasters and environment catastrophes. In this sense, the possible earthquakes are very strong hazard. Therefore, the permanent seismic observations and corresponding NPS protection have the most importance. The complex program to develop the national system of the seismic observations and to raise the population safety in the seismic hazardous regions has been worked out in the Ukraine. In particular, the program foresees to re-supply the NPS with modern seismic control equipment. In frame of that program, the State Scientific Industrial Association "Metrology" (Kharkov) develops, manufactures and tests the various types seismic sensors intended for operation at the NPS prediction systems. To verify those sensors, we have developed pendulum calibrator allowing to attest it directly at the station. It is foreseen to equip all the Ukrainian NPS with such technique. As a result, the NPS reliability and safety will be improved.

ACTIVE TECTONIC STRUCTURES IN THE PADANA PLAIN: NEW DISCRIMINATION STRATEGY FROM A JOINT STUDY OF GEOMORPHIC AND GEODETIC LEVELING DATA

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We compared geomorphic anomalies with a wave-length comparable to that of tectonic structures of crustal significance (10-30 km), with elevation changes from successive leveling surveys (1985-1953, Italian first order network) for two sample areas of the Padana Plain, located near Mantova and NW of Treviso. Both areas are characterised by clear anomalies in the drainage pattern, which is highly sensitive to vertical motions. The analysis of the leveling data shows differential elevation changes in agreement with the strain field inferred from geomorphology. For each area we estimated the geometric and kinematic parameters of the crustal fault that fits best the observed geomorphic and geodetic anomalies. To address the question of whether the fault is mainly creeping, as suggested by the paucity of background seismicity, or potentially seismogenic we compared the strain rate inferred from geodesy with that derived from geomorphology. We found that the geodetic rate (a) accounts for only a small fraction of the rate detected from geomorphology, and (b) does not seem large enough to induce the observed perturbations of the drainage. To explain the strain surplus inferred from geomorphology we suggest that the hypothesised faults could generate infrequent earthquakes up to M 6.2-6.5, which would induce the observed instantaneous yet localised diversions of the water flow.

MAPPING SUBSURFACE FAULTS USING REALTIVE LOCATIONS AND FAULT PLANE SOLUTIONS OF MICROEARTHQUAKES

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Relative locations of clusters of similar microearthquakes can be determined with uncertainties less than 10 m. The mean distance of a group of earthquakes from the best fitting plane through the group is often comparable to the relative location uncertainty of individual events. A simple interpretation of the best fitting plane through a dense cluster of earthquakes is that it coincides with the common fault plane of the group. Fault plane solutions provide independent estimates of fault orientations. These methods have been applied to tens of microearthquake clusters in Iceland. In the transform zones in north and south Iceland the fault orientations determined in this manner agree closely with field observations. Near the Hengill triple junction and volcano complex in SW Iceland the pattern is more complicated and fault orientations often deviate markedly from fault aspects determined by surface observations.

FAULT-FRAGMENTS AND RELATED ACTIVE DEFORMATION: IMPLICATIONS FOR THE SEISMIC HAZARD ASSESSMENT

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We study examples of coseismic surface faulting in different tectonic regions and it appears that in many cases, earthquake faults are not characterized by straightforward clearly expressed surface ruptures. In order to address this problem we use the fault fragment model which refers to the minimum fault-area for which the coseismic deformation is visible at the ground surface (Meghraoui and Camelbeeck, 1996). The maximum fragment size is the fault rupture for which $L^* = H/k_l$ (H is seismogenic layer depth, k_l constant strain level) holds, reaching ~ 10 km rupture length and producing 10^{17} - 10^{19} N.m. of moment-earthquakes. Furthermore, the size of fault fragments coincides with the dimension limit at which the self-similar behavior of earthquakes mechanics changes, i.e., a break in self-similarity at the limit between small and large earthquakes. The fault fragment may represents the basic crustal element by which the seismic strain is released in active zones with distributed deformation. In this context, the fault emergence and visibility might be controlled by local tectonic pattern (block tectonic), inherited and new structures, fault geometry and dimensions and related earthquake-size. In many active zones, the seismic hazard assessment depends on a complete inventory of fault fragments capable of producing moderate-sized but damaging earthquakes.

SEISMOTECTONICS AND SEISMIC HAZARD ASSESSMENT OF LIBYA

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Libya, Situated on the Mediterranean foreland of the African shield, is not commonly thought of as being seismically active. However, several earthquakes of magnitude >6.0 have occurred there within this century. Data from earthquakes that have occurred in Libya was gathered and investigated in order to gain better knowledge regarding the seismotectonics and seismic hazard assessment. We used a combination of seismicity, first motion and waveform modeling along with all available geological information. Focal mechanisms suggest a rapid change in the direction of maximum compressive stress (NNW to NE-SW) within the offshore portion of the African plate. There also appears to be a change in the stress regime across Libya, with dip-dip faulting more prevalent in eastern Libya. The relatively aseismic central portion of Sirt basin appears to divide these stress regimes. Libya is divided into four seismic zones. The NW-SE trending Hun graben seismic zone is considered the most seismically active zone in Libya. Continued seismicity to the north along this zone could pose a serious hazardous to the major cities that lie along it.

TWO-WAY COUPLING BETWEEN ERUPTIONS AT VESUVIUS AND SOUTHERN APENNINE EARTHQUAKES BY ELASTIC STRESS TRANSFER

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During the past thousand years, eruptions of Vesuvius have often been accompanied by large earthquakes in the Apennine chain 50-60 km to the northeast. Statistical investigations had shown that earthquakes often preceded eruptions, typically by less than a decade, but did not provide a physical explanation for the correlation. We explore elastic stress interaction between earthquakes and eruptions, under the hypothesis that small stress changes can promote events when the Apennine normal faults and the Vesuvius magma body are close to failure. We show that earthquakes can promote eruptions by compressing the magma body at depth and opening suitably oriented near-surface conduits. Voiding the magma body in turns brings these same normal faults closer to Coulomb failure, promoting earthquakes. Such a coupling is strongest if the magma reservoir is a dike oriented parallel to the Apennines and the near-surface conduits and fissures are oriented normal to the Apennines. This preferred orientation suggests that the eruptions issuing from such fissures should be most closely linked in time to Apennine earthquakes. We use our modeling results to select those earthquakes and eruptions for which the coupling is favored and we performed a new statistical analysis, which yields a better correlation with respect to the Marzocchi et al.'s [1993] results.

SEISMIC HAZARD ASSESSMENT BY USING ACTIVE FAULT DATA

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The Map of active faults of Eurasia, 1:5000000, was compiled as a part of the ILP Project II-2 "World map of major active faults". To find the general criteria of intensity of active faulting, the components of tensor of recent deformation rates were calculated and mapped in the Alpine-Himalayan collision belt by using active fault data. Areas of concentration of the deformation are seen in the maps. They form wide zones along the recent plate boundaries, in their junctions, and along some other active fault zones of the higher seismicity. Active faults, differentiated by their activity, were used (together with some parameters of seismicity) for mapping seismotectonic domains of the northern Eurasia and calculating their seismic potential [Shebalin et al., 1995]. The map of the domains have been used for calculating strong motions and general seismic zoning. To detailize the seismic hazard assessment, active tectonics of the earthquake source zones of the Arabian-Caucasus collision region were studied. Tectonic regularities of crustal seismicity are not limited by interaction of plates and crustal blocks. Our studies in the North Anatolian fault zone showed that average rate of the seismotectonic deformation (during the 500-year seismic cicle, not the XX centure) is higher in some sites than average rate of the plate interaction motion because of higher vertical component of the seismic displacements. Thus, some local factors increase rate of the elastic deformation and produce additional vertical seismic displacements. These sites are located in the ophiolite zones. We found concentration of strong earthquake epicentres in the ophiolite zones in all the Arabian-Caucasus collision region. Perhaps, the additional vertical seismic displacements depend on stress, produced by increase of volume of peridotites and basalts because of mineral transformations by water circulation in the fault zones.

PALEOSEISMOLOGICAL INVESTIGATIONS ALONG THE MOSCARELLO FAULT, MT. ETNA VOLCANO (SICILY)

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A program of trench investigations and geomorphological analyses has been recently initiated at Mt. Etna, whose eastern flank is affected by very active, mainly NNW-SSE-striking, normal faults, the "Timpe" fault system, which represents the northermost inland extension of the Malta Escarpment. This study focuses on the Moscarello fault, which displaces Late pleistocene-Holocene lava flows and alluvial fan deposits for a length of ca. 10 km. The maximum observable throw, more than 125m in less than 100,000 years, is attained in the northern sector of the fault, that borders the Fondo Macchia tectonic basin. This depression has hosted some of the largest earthquakes occurred in the volcanic area, with generally shallow sources and macroseismic intensities reaching the IX-X degree MSK. Coseismic surface faulting, up to 6 km long and with 30 to 90 cm of vertical offsets, was associated to the 1855, 1865, 1911 and 1971 earthquakes. Hence, two trenches were excavated along the 1971 coseismic scarp at Fondo Macchia, aiming at reconstructing the fault behaviour on a longer time-span and at better understanding the relationship between the "Timpe" system and the active Malta escarpment, suspected source of the major earthquakes in SE Sicily. Here, the first results of stratigraphic and geomorphological analyses and radiocarbon dating are presented.

NH3 Earthquake risk mitigation (co-sponsored by SE)

05 Landslide hazards in seismically active regions

Convener: Wasowski, J.
Co-Convener: Del Gaudio, V.

RECONNAISSANCE AND DESCRIPTION OF LANDSLIDE DAMS OF SEISMIC ORIGIN IN SOUTH-EASTERN SICILY

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Among the secondary effects induced by seismic ground shaking, this paper focuses on the analysis of earthquake-triggered landslide dams. When an earthquake occurs and is strong enough to trigger slope movements, the blockage of a river is frequent in narrow, steep valleys; consequently, an impoundment upstream of the landslide forms and, if the dam does not fail, is gradually silted up.
A sample of eight earthquake-triggered landslide dams in SE Sicily is presented and discussed in this paper. The origin of these landslides is most likely related to the occurrence of the strong earthquakes which periodically shake this sector of Southern Italy: three seismic events having intensity equal or greater than X in this millennium, and an unknown, but presumably conspicuous, number of comparable events in previous times.
Each landslide dam was analyzed in relation to local geology, type and dimensions of slope movement, presence and characters of silting up deposits, conditions at present. The list of relevant question proposed by Schuster and Costa (1986) and the classification scheme proposed by Costa and Schuster (1988) were followed, in order to obtain descriptions of the landslide dams as complete and consistent as possible. A sketch of the overall characteristics of these dams is eventually given.
The information coming from this work could be used for a twofold purpose: 1) to develop a database of earthquake-triggered landslide dams in SE Sicily; 2) to evaluate the risk, if any, related to the actual dams. Furthermore, the analysis of landslide dams distribution and characteristics in relation to main seismogenic areas could provide useful information in the attempt of identifying the most typical geomorphic and geologic conditions under which, should a moderate to strong earthquake occur, landslide dams could more likely develop.

EARTHQUAKE RELATED GRAVITATIONAL PHENOMENA IN THE UMBRO-MARCHE APENNINES (CENTRAL ITALY): THE CASE OF THE SEPTEMBER - NOVEMBER 1997 SEISMIC EVENTS

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During autumn 1997 a very strong sequence of seismic events struck a vast area in the Umbro - Marche Apennines, an east verging thrust belt made up in Neogene times and subsequently dislocated by normal and transcurrent faults which are still active. From September 26 (at 0.33 GMI) to mid-November, five main shocks (with magnitude ranging between 5.5 and 6.0 MW) and a large swarm of minor shocks caused 12 deaths and detroyed or heavily damaged a large number of building including historical monuments of inestimable value such as the monastery of S. Francesco in Assisi. The epicenters were located around the Colfiorito basin, an intermontane tectonic depresion berdered by NNW - SSE trending active normal faults. The earthquake produced wide spread surface effects including ground fracturing and faulting, debris compaction and a large number of gravitational phenomena of different type and size. Rapid mass movements such as rock fall, debris fall and debris flow were directly triggered during the earthquake shaking, both by ground fracturing and oriented accelerations, while slide phenomena in clay-rich materials were activated later, mostly after heavy rainfall infiltration through open gran fractures. Also deep seated gravitational deformation phenomena on limestone slopes, such as at Mt. Frascare and Mt. Fema, were ractiveted by the earthquake shocks, even at some distance from the epicentral area. All the above phenomena have been examined and mapped in order to compare their distribution pattern with that of the isoseismal lines. The resalting data may be useful for future land planning and management in the area.

GENESIS OF THE SEISMODISLOCATIONS IN THE EPICENTER OF THE RACHA EARTHQUAKE

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(1) The destructive Racha earthquake occured on April 29, 1991 in the northern part of Georgia. The earthquake of magnitude M=6.9 and intensity in epicentre IX (MSK scale) had a focus at about 5km depth. (2) Analysis of seismodislocations emerged in the epicentral area showed that they are mainly rockfalls, landslides, rock avalanches and displacements in unstable degradational slopes. Much rare are small amplitude fractures and cracks, especially of strike-slip and combined character (reverse fault-shear, normal fault-shear, etc.). The latter are most frequently grouped in N or NW direction. For the earthquake of such great energy the secondary dislocations turned out to be dominating,, whereas the primary ones have subordinate character. This phenomenon may be explained by intensely dissected mountainous relief previously prepared by tectonic and erosional processes and enhanced by superimposing the gravitational effect. (3) The concentration of landslide-avalanche manifestations along the zone of the deep fault, separating the stable Georgian block from the folded zone of the Southern slope of the Greater Caucasus, in our opinion, may be explained by complex kinematics of the collision of the two opposite-directed mass movements separating here structural-tectonic domains of the Greater and Lesser Caucasus.

WATER BALANCE MODEL OF A LANDSLIDE DAMMED LAKE IN THE ANDES OF NW ARGENTINA (26°S, 66°W)

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A water balance model has been applied to a paleolake existing about 35 kyr BP in the Valles Calchaquies of northwest Argentina. This lake resulted from damming of the Rio de las Conchas by a catastrophic landslide in the tectonically active transition between the Sierras Pampeanas and eastern Cordillera geologic provinces. Similar to other ephemeral lakes in northwest Argentina the existence of this lake coincides with the Pleniglacial wet period (40 - 25 kyr BP). Field observations indicate that the disappearance of the lake was due to clastic infill rather than increased evaporation. Paleoenviromental reconstructions based on varved lake deposits provide detailed information on the seasonality of river discharge and sediment sources within the basin and are used to define boundary conditions for the model. Based on these parameters, different scenarios were developed for climatic conditions consistent with the existence of the lake. A higher precipitation must coincide with increasing cloudiness and a weaker wind-regime combined with lower temperatures in order to establish and maintain such a lake. The model, adapted from Blodgett et al (1997), incorporates mean cloudiness and wind speed as well as temperature and precipitation in estimating evaporation and resulting lake levels. Additionally, the model now incorporates new modules accounting for spatial variation of rainfall and distribution of source rocks in the catchment area.

LARGE APENNINE LANDSLIDES ALONG ITALIAN ADRIATIC FOREDEEP STUDIED BY L-TRANSFORMS (VISCO-ELASTIC DOMAIN)

The Adriatic Slope of the Apennine Range is characterised by a number of large landslides - permanently affecting rural lands, roads, towns and also rivers - in particular along the Adriatic Foredeep, marked by a continuous gravimetrical through, modulated by three gravimetrical highs, located near the geomorphological evidences of Monte Conero, Montagna Maiella and Monte Vulture..
In the frame of a broader geophysical research, seismo-genetic visco-elastic geostructures have been suggested, which are able to transfer seismic energies to the Earth surface, owing to viscous connections with deep, thin viscous geostructures, squeezed by African Plate effects, also according to the secular anticlockwise rotation of the Italian Penin ula. These basic models are suggested by gravimetrical maps, filtered at sub-regional scales: their squeezing appears to be one of the major geophysical causes of landslide generation s, owing to both the nearly continuous modifications of local slopes at the surface and the triggering effects caused by very frequent earthquakes.
L-Transform methods help to deal with different possible (also underhand) approaches, which induce unstable masses located upon those Apennine slopes to start their dangerous trends.

EARTHQUAKE-INDUCED LANDSLIDES IN SAGUENAY LOWLANDS (QUƑBEC, CANADA) : IMPACT OF THE 1663 CHARLEVOIX EARTHQUAKE

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Our research work on physical impacts of the July 1996 Saguenay deluge has led us to define a 14C-based reconstruction of the regional dynamics of landslides. Our first set of dates indicates that distinct generations of landslides have dissected postglacial marine terraces during the last millennia. Ages related to the most recent period of extensive landsliding range from 320 ░ 60 BP to 240 ░ 40 BP ; once calibrated into calendar years (1627 - 1677 cal AD), they are centered around the well-known February 1663 earthquake in Charlevoix, 100 km away from the Saguenay region. Data from tree-ring analysis of tree trunks buried in landslide sediments strengthen the idea that the 14C-dated landslides were triggered by the 1663 major seismic event. Precise dating of a large number of landslides in the Saguenay region provides new insights on the relative importance of different natural causes for slope failures in postglacial marine clays. It also contributes to establish the distribution of landslides induced by the 1663 earthquake. In addition to the Mauricie and Charlevoix regions where large landslides have previously been linked to the 1663 event, the Saguenay lowlands are another region where this M=7+ (estimated) earthquake had strong geomorphic impacts.

Surface effects induced by the 26.09.97 Umbria –Marche earthquakes

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In the paper the surface effects induced by the 26/9/97 earthquakes which stroke Umbria and Marche regions (central Italy) will be described and discussed. The two main events occurred at 00h33m and 09h40m UTC, with magnitude M_d equal to 5.5 and 5.8 respectively (ING, 1997).The authors have examined a wide area (about 700 Km^2) around the two epicentral zones. The effects have been catalogued in: rockfalls and landslides, subsidence phenomena, hydrological phenomena, ground fractures. Frequent rockfall phenomena along the sides of the roads have been observed. Huge phenomena occurred in Stravignano-Bagni and Sorifa towns, where volumes up to thousands of cubic meters failed in the Travertino rock formation. Three major subsidence phenomena will be discussed, which occurred at Bagnara and Le Moline towns and at Acciano Dam. Ground fractures have been observed all over the area; their areal distribution, length and orientation have been studied, and correlations with the surface faulting systems have been found out.

SPATIAL HAZARD ASSESSMENT FOR LANDSLIDES UNDER SEISMIC CONDITIONS

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The stability of natural slopes is influenced by geographical, geological, geomorphological, geotechnical and hydrological factors. Over the last fifty years or more, a great deal of research has been carried out in many countries to understand the fundamental causes and mechanisms of slope instability. Methods of geological and geotechnical modelling and analysis have been developed to understand landslides which have occurred and to predict future instability. The roles of triggering factors such as deforestation, development, rainfall and earthquakes have been explored. It is now acknowledged widely that accurate prediction of slope stability is often difficult due to uncertainties concerning geological details, geotechnical properties as well as triggering factors. Seismic effects of triggering landsliding are highlighted in this paper.

In this paper, attention is drawn to hazard assessment facilitated by GIS-based techniques for mapping and risk assessment. So far this approach has been validated for rainfall-triggered landslides in the Illawarra region. It is argued in this paper that a similar approach can be developed for seismically active regions. Spatial distribution of landsliding can be studied in a rational and systematic manner and thus spatial 'probabilities of landsliding can be correlated to geological and geotechnical factors. The methods and approaches discussed here enable assessment as well as updating of hazard.

DEVELOPMENT OF A LANDSLIDE HAZARD MAP FOR NORTHWEST ARGENTINA

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A map of landslide hazards is produced for northwest Argentina which provides a synthesis of geologic, paleoclimate and modern meteorological studies in this area (as presented in this session). These complementary studies have described geological preconditions for landslide occurrence, source lithologies, seismic triggers and required relief contrasts as well as indications of additional, more frequent events in the past resulting from moister climates. The present synthesis incorporates these results with modern measures of rainfall provided by satellite-based retrievals and supported by ground station records to determine regions of particular landslide susceptibility due both to existing preconditions and likelihood of additional rainfall triggers. Relevant datasets are compiled and analysed within a Geographic Information System (GIS) focusing on topographic analysis (slope and relief), rainfall (ground station and satellite) and lithology (field observations and Landsat TM classification). This analysis identifies areas of potentially higher susceptibility and impact due both to rainfall distribution and existing development.

DEEP-SEATED GRAVITATIONAL SLOPE DEFORMATIONS (DGSD) AS A NATURAL LABORATORY OF BRITTLE ROCK DEFORMATION - IMPLICATIONS TO ROCK SLOPE HAZARDS.

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In the central mountain chain of the Eastern Alps slope instabilities of Sackung type morphology are common phenomenons. Three general types of Sackung, interdependent on both host rock lithologies and inclination of the main foliation, can be distinguished. Thereby, surface slope failure geometry do attest normal fault tectonics. Associated subsurface structures indicate deformation of affected host rocks close to pure shear as well as close to simple shear regime. Formation of new generated fractures in cooperation with reactivation of preexisting joints provide penetrative and also deep reaching relaxation of mountain ridge brickwork. Ongoing gravitational creep of relaxed rock masses is responsible for excessive processes of erosion, increasing provocation of large scale rock avalanches and torrentiality. Especially in the area of DGSD rock fall events are frequent. Therefore, these movable rock masses triggering to DGSD do represent sources of several mass movement hazards and simply can be aktivated by earthquake events.

OCCURRENCE AND EVALUATION OF LANDSLIDES GENERATED BY EARTHQUAKES

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Seismic shaking is one of the main agents generating landslides, and large earthquakes may produce tens of thousands of landslides, dislodging more than a billion cubic meters of material from slopes and causing significant economic losses and casualties. These landslides may be classified into three main categories: The first includes such highly disrupted landslides as rock falls and debris slides, which occur on steep slopes and are overwhelmingly the most abundant. The second category involves deeper-seated and more coherent bodies such as rotational slumps and translational block slides, which may cause considerable damage largely because of their occurrence on gentler slopes. The third category includes partly to completely liquefied masses, such as lateral spreads and mud flows, which may originate on still gentler slopes. The total area affected by landslides in earthquakes with magnitude, M may be approximated by the regression relation $\log_{10}A = M-3.46$, where the area, A is in km^2. The total volume of landslide material may be approximated by the relation $\log_{10}V = 1.45M-2.50$, where the volume, V is in m^3. The susceptibility of slopes to failure may be evaluated using either geologic criteria or engineering slope-stability analysis. For the most common types of landslides, the most important geologic characteristics are degree of weathering, strength of cementation, fracture spacing and openness, and ground-water conditions.

IMPORTANT BOUNDARY CONDITIONS CONTROLLING ROCK-AVALANCHE DISTRIBUTION IN SEMI-ARID NW-ARGENTINA

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Landsat TM analysis of the semi-arid Puna and adjacent Eastern Cordillera and Sierras Pampeanas (24° - 28° S) has revealed the existence of at least 53 rock-avalanche deposits with volumes in excess of 10^3 m^6 formed by the collapse of entire mountain fronts. Their spatial distribution is not random, but show remarkable clustering along neotectonic active mountain fronts. Detailed field studies reveal five principle controls on the distribution of these events. The source area of the rock avalanches has two topographic constraints, vertical relief contrasts have to be higher than a threshold of 400 m (I) and the slope inclinations have to be steeper than 20° (II). Furthermore, rock avalanches occur in three types of lithology (III), granites, low-grade metamorphic rocks, and coarse clastic sediments. Structural controls (IV) are very important. All avalanche deposits occur along neotectonically active mountain fronts. In addition planar structures like bedding planes, exfoliation joints, minor faults and foliations dip in all cases toward the valley. Finally, major slide clusters occur along mountain fronts which experienced a Quaternary reverse-fault reactivation of former strike-slip faults (V). Although three of the major slides are about 30 ka old and may correspond to a more humid interval in South America, the trigger mechanism for the majority of these landslides is interpreted to be seismic shaking in accordance with important landslide events elsewhere.

LANDSLIDE HAZARD MANAGEMENT AND PREDICTION OPTIONS: SOME STRATEGIES FOR THE SIKKIM HIMALAYA, INDIA

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Sikkim Himalayan terrain is frequently affected by the single worst natural hazard manifested as landslides. The causes are characteristic fragile host mountain terrain accompanied with adverse natural events as well as anthropogenic activities. Himalayan region in general is considered to be seismically active. Physiographically more sensitive zones with slope instabilities undergo high intensity rainfall. The most common landslide triggering factor here is the cloud burst which is highly concentrated rainfall over a small area lasting a few hours. The earthquake tremors with epicentres in North Eastern states preceeding some of the earlier events are believed to have caused instabilities which caused landslides later on during high intensity rainfall. Therefore, the role of earthquakes as an indirect cause contributing to such events of mass movements leading to loss of lives and other related impacts have been analysed. This study is aimed at evolving risk management and prediction strategies taking into account assessment of some of the past events of significance with the consideration of triggering causes preceding these. The general geological set-up, meteorological, seismological and geo-environmental factors have been correlated. Following are the overall envisaged approaches: (i) Identification of landslide susceptibility zones for sample areas based on high resolution remote sensing data, topographic maps and ground level observations. (ii) Identifying areas and meteorological situations that favour the occurrence of cloud burst. (iii) A correlation of susceptibility zones with the triggering events in retrospect to establish threshold factors for prediction. (iv) Strategies to prevent and reduce the damages in the disaster. The study also aims to demonstrate the utilization of Geographical Information System (GIS) based approach for an effective collection, analysis, storage and display of information for the management and prediction of this natural hazard. The scope of application remains wide where this shall be of assistance to the planners, policy makers and administrators towards hazard prediction, early warning, control and management.

ASSESSING HAZARDS FROM SEISMICALLY TRIGGERED LANDSLIDES: AN OVERVIEW OF THE STATE OF THE ART

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Landslides are a major cause of damage in most large earthquakes. Triggered landslides commonly damage and destroy homes and other structures, block roads and rail lines, sever pipe and power lines, and dam streams and rivers. Over the past 20 years, our understanding of earthquake-triggered landslides and their impact has increased greatly. In particular, significant progress has been made in (1) characterizing the environments that are most susceptible to seismically triggered landslides, (2) quantifying the relative abundance of various types of landslides likely to be triggered, (3) documenting the threshold shaking conditions needed to cause failure, and (4) developing methods to model coseismic landslide deformation. But even in light of this progress, several fundamental advances are still needed to more accurately predict where and in what conditions earthquakes are likely to produce widespread damaging landslides. Some innovative research aimed at advancing the state of knowledge includes (1) developing simplified methods to model earthquake-triggered landslide movement, (2) conducting field experiments by permanently instrumenting landslides to directly measure coseismic landslide behavior, and (3) developing methods to use high-resolution, computer-based geographic information systems (GIS) to quantitatively assess and map regional seismic landslide hazards.

HYBRID PROBABILISTIC-DETERMINISTIC APPROACH FOR MAPPING LANDSLIDE VULNERABILITY TO EARTHQUAKES USING GIS TECHNIQUES

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Landslides triggered by earthquakes represent a common phenomenon, recent experiences (Umbria-Marche event, 26/09/97) show how the role of unstable slopes is fundamental for post-earthquake reconstruction and for land use planning. The most common approach used to determine slope vulnerability to a seismic event is to calculate the critical horizontal acceleration (kc) which can trigger the terrain, using deterministic methods. For thin soil layers on hillside slopes the infinite slope model is commonly used for individual slopes, but recently it has been applied over large areas, especially after the increasing role played by the Geographic Information Systems (GIS), whose importance is mainly due to their capacity of storing, updating and analysing data in relatively short time. The application of deterministic models often implies the detailed knowledge of geotechnical, geometric and hydrogeological parameters and for this reason the application over large areas can lead to errors, as the outcome is represented by unique values of Kc. To overcome this limitation a solution can be a parametric analysis, that is using geotechnical parameters varying from a maximum and a minimum value and assuming either dry or variable saturation condition degrees. The suggestion here proposed is the adoption of statistical techniques to obtain a distribution of Kc values. A Monte Carlo simulation is proposed adopting probabilistic distribution of geotechnical, geometric and hydrogeological parameters, through the following phases: identification of landslide mechanisms, selection of slope stability method, selection of terrain unit, input data layer preparation, analysis. The procedure was applied on an area of the Serchio river (Toscana, Italy).

CLIMATE-TRIGGERED VARIATIONS IN DIATOM ASSEMBLAGES IN A PLEISTOCENE LANDSLIDE-DAMMED LAKE IN THE VALLES CALCHAQUIES, NW ARGENTINA (26°S, 66°W)

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Two massive rock avalanches dammed a lake in the Valles Calchaquies, NW Argentina about 35 kyr BP. In order to evaluate climate as a major influential factor in rock-avalanche development, varved deposits of this lake have been studied in great detail. The 1 to 10-mm-thick varves consisting of fine-grained detrital material are topped by thin layers of pure white diatomite. From diatom analyses we infer a significant impact of climate-triggered hydrological and chemical changes on the ecology of the lake system. During the wet years characterized by an enhanced influx of reworked Fe-rich muds, the diatom flora was dominated by the planktonic species *Cyclotella agassizensis* Hakansson. During the following drier years, *Aulacoseira granulata* (Ehrenberg) Simonsen were abundant. For these dry years increasing numbers of the morphotype *Aulacoseira granulata f. curvata* are observed. According to modern ecological observations of similar species, we interpret the increased Fe-supply as the most likely trigger for the dramatic increase in the *Cyclotella* population. The shifts towards higher numbers of the curved *Aulacoseira* indicates gradually decreased Si supply in the water body during the dry years. These climate-triggered changes in the lake ecology show mean periodicities of 3-5 and 10-13 years suggesting an influence of the El Nino/Southern Oscillation teleconnection and tropical Atlantic sea-surface temperature dipole. These climate oscillators also influence modern rainfall but with different intensity. The reconstruction of this interannual rainfall variability is of great importance in the assessment of the role of climate in landslide generation. Moreover, the dynamics of the paleo-lake provides important constraints for a lake balance model (presented in this session).

EARTHQUAKE-INDUCED GROUND FAILURES IN ITALY

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ABSTRACT.
The National Catalogue of the ground Displacements Induced by strong Earthquakes in Italy (C.E.D.I.T., release 1.1), is here presented. The catalogue contains information regarding the soil displacements triggered by the earthquakes occurred in Italy in the last millennium with a nominal epicentral intensity equal to or greater than 8 in the MCS scale. The catalogued effects are the following: landslides, liquefaction, surface faulting and fractures, topographic changes of the ground level (subsidence, settlements, and so on). Each effect is described in terms of seismological parameters of the triggering earthquake, site coordinates and administrative code, lithology and kinematics type of phenomenon. The historic or scientific source referring to the effect is always preserved, to allow a retrieval of the deduced phenomena.

EARTHQUAKE RELATED LANDSLIDES IN GREECE

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The area of Greece is the most seismically active in Western Eurasia. A large number of strong earthquakes have been reported to cause landslides and other ground failures. An effort has been made to compile data on earthquake related landslides in Greece from the antiquity up to the present. Preliminary results have been obtained on the landslide characteristics, the maximum epicentral distance, D, at which they may occur as a function of the earthquake magnitude, M, and the frequency of landslide occurrence as a function of M. The results are compared with those reached at other regions of the world and are discussed as for their value for seismic and landslide hazards assessment.

SEISMICALLY-INDUCED LANDSLIDE DISPLACEMENTS: A PREDICTIVE MODEL.

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ABSTRACT.
A model for predicting earthquake-induced landslide displacements is shown. The model has the purpose to provide a simple way to predict the coseismic displacements affecting a sliding mass subject to earthquake loading. Critical accelerations are investigated with regard to the mechanical soil properties, pore pressure distribution and geometrical configuration of the slopes. The acting seismic forces are investigated in terms of energy radiation of the source, propagation and site effects, based on 190 accelerometric recordings coming from 17 Italian earthquakes with magnitude between 4.5 and 6.8.
The implemented displacement model is the well-known Newmark sliding bolck model, improved by taking into account the degradation of the mechanical soil caracteristics.

A SEISMIC LANDSLIDE SUSCEPTIBILITY RATING OF GEOLOGIC UNITS BASED ON ANALYSIS OF CHARACTERISTICS OF LANDSLIDES TRIGGERED BY THE JANUARY 17, 1994, NORTHRIDGE, CALIFORNIA, EARTHQUAKE

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One of the most significant geologic effects of the 17 January 1994 Northridge, California, earthquake ($M = 6.7$) was the triggering of thousands of landslides over a broad area. Some of these landslides damaged and destroyed homes and other structures, blocked roads, disrupted pipelines, and caused other serious damage. Analysis of the distribution and characteristics of these landslides is important in understanding what areas may be susceptible to landsliding in future earthquakes. We analyzed the frequency, distribution, and geometries of triggered landslides in the Santa Susana 7.5' quadrangle, an area of intense seismic landslide activity near the earthquake epicenter. Landslides occurred primarily in young (late Miocene through Pleistocene) uncemented or very weakly cemented sediment that has been repeatedly folded, faulted, and uplifted in the past 1.5 million years. The most common types of landslides triggered by the earthquake were highly disrupted, shallow falls and slides of rock and debris. Far less numerous were deeper, more coherent slumps and block slides, primarily occurring in more cohesive or competent materials. The 1,562 landslides in the Santa Susana quadrangle were divided into two samples: single landslides (1,502) and landslide complexes (60), which involved multiple coalescing failures of surficial material. Landslide morphologies were described by computing simple morphometric parameters (area, length, width, aspect ratio, slope angle). To quantify and rank the relative susceptibility of each unit to seismic landsliding, we calculated the proportional landslide area and frequency of landslides within each geologic unit. Susceptibility categories include Very High Susceptibility (> 5% landslide area or > 30 ls/km^2), High Susceptibility (1-5% landslide area or 10-30 ls/km^2), Moderate Susceptibility (0.5-1% landslide area or 3-10 ls/km^2), and Low Susceptibility (< 0.5% landslide area or < 3 ls/km^2).

STUDYING THE SLOPE-PROCESSES IN SEISMIC-ACTIVE REGIONESWITH THE HELP OF REMOTE SENSING

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This method was used and examined at 4 objects in seismic- active regions in Middle Aisa and the Caucasus alpine belt. In the region of Haitskoye earthquake of 1949 in Middle Aisa the mud-rock flood over-covered the settlement Haite. The heigint sediment there is about 40m. After the earthquake in the North Caucasus in 1970 the mudstream damed river Sulak. In Dagestan near settelment Mochok was formated the mountain lake with the depth of 70m as a result of movement of the huge masses of rocks. The formation of mud-torrent was stopped by engineer-geological works.In the region of Djavskoye eathguake in South Osetya in 1991 river Patsa was damed by the large landslide and formated lake was a real danger for the settlement Tshinval. In all these cases theodolitic and field survey was made and aerial survey materials obtained before the earthquakes and after them were also deciphered.

THE ROLE OF CLIMATE AS A PREPARATORY OR TRIGGERING FACTOR IN THE GENERATION OF CATASTROPHIC LANDSLIDES IN NW ARGENTINA

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In seismically active regions the deposits of landslide-dammed lakes can be used as natural archives for past seismic activity and climatic shifts as possible trigger mechanisms for mass movements. Here we present first evidence that the temporal clustering of landslides in NW Argentina could be related to both enhanced humidity and seasonality. First, new AMS radiocarbon data from the deposits of landslide-dammed lakes in the Valles Calchaquies (S26° W66°) and the Que. del Toro (S25° W66°) show that these mass movements occurred during the Pleniglacial wet period (40 - 25 kyr BP). During this time, an intensification of the South Atlantic anticyclone and a meridional contraction of the westerly belt lead to moderately cold and relatively wet conditions as reported from other paleoclimate records. Second, detailed analysis (presented in this session) of annual-layered lacustrine strata suggest enhanced inter- and intraannual fluctuations in precipitation. These variations show mean periodicities of 3-5 and 10-13 years suggesting an influence of the El Nino/Southern Oscillation (ENSO) and Atlantic sea-surface temperature dipole. The Atlantic dipole slightly increased rainfall every 10-13 years as today. In contrast, the past ENSO influence was different from the present-day situation due to spatial shifts in ENSO-related rainfall anomalies in South America. Whereas modern rainfall is reduced during El Nino every 3-5 years, the sedimentary record shows strong evidence for dramatic rainfall events and river discharge with ENSO-type periodicites. Both increased humidity and seasonality are believed to reduce thresholds for the generation of catastrophic mass movements in NW Argentina.

Influence of the topographic amplifications under dynamic loading on the slope stability.

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The evaluation of the slopes stability under dynamic loading requires the determination of the forces of inertia. Up to now, the usual practices (pseudostatic or Newmark methods) consider an uniform distribution of these forces within the slope. In reality, forces of inertia vary locally within the slope, and result from the interferences between the incident waves and the various waves reflected, refracted and diffracted on the topography and the internal geological structures. At the surface, these interferences produce amplifications in the crest (topographical site effects), loading to easier shallow instabilities. In the case of deep-seated slides, the distribution of the forces of inertia has been studied as a function of the slope angle, the Poisson ratio and the frequencies of the incident signal. Transfert functions have been built for computing the mean accelerations to apply to the potential unstable mass.

MASS MOVEMENT AND SEISMIC HAZARDS IN CARAMANICO TERME (ITALY): SOME LINKS

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Mass movements and earthquakes represent two major geological hazards in the municipal territory of Caramanico (south-central Apennines). Most of the recent damaging landslides can be associated with periods of prolonged precipitation, represent remobilizations of older slides and exhibit low velocity. Thus their space distribution may be predicted and the temporal occurrence anticipated in reference to rainfall/groundwater monitoring. This means that, despite their considerable size and frequency (resulting in large economic losses), the rainfall-driven movements represent a low risk to humans. The slope failure hazard in relation to earthquake triggering has received little attention although the seismicity of the area is high. The intensities up to IX degree (MCS) were estimated for two historic events (1456 and 1706), whereas intensity VII-VIII was reached twice in this century. Seismic hazard evaluations indicate that intensity and PGA have 10% probability to exceed respectively the thresholds of VIII and 0.2 g in 50 years. The contemporaneous occurrence of seismic shocks and landsliding was registered on three occasions in the last four centuries (1627, 1706, 1984). These events, with local intensities ranging from VI to IX generated mass movements varying from a full-scale multiple rotational slope failure to rock/debris falls. They all occurred in the southern periphery of the town, where the debris-mantled hillslopes, underlain by overconsolidated mudstones, are capped by up to 100 m thick carbonate megabreccias. After examining the 1984 event, which produced several rockfalls (with some car-sized blocks reaching the roads and inhabited area), this paper draws attention to the rockfall hazard. Although an accurate definition of rockfall susceptible areas can be derived from a site-specific geological/geotechnical investigation, the possibility of seismic triggering complicates the prediction of the temporal occurrence. The probabilistic estimates of future events may be of limited practical value to local administrators concerned with short-term hazard reduction.

Monitoring Aseismic Slope Activity in Northern Israel: A Key to the Comprehensive Assessment of the Seismic Triggering of Landslides.

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Intense seismic activity on steep, unstable slopes, combined with abundant rainfall contribute to increase the present vulnerability of populations and infrastructures in northern Israel as well as neighboring areas. Multi-disciplinary monitoring of the non-seismic activity of unstable slopes is the first step towards the prediction of their potential co-seismic behavior. Located in an area known for its current instability and past sensitivity to earthquakes, the research site consists of a dip-slope landslide in which marls and chalks fail on bituminous shales. Monitoring rainfall, water table level fluctuation, surface and subsurface displacement and radon emission during the last 24 months has led to the quantification of the present aseismic slip rate and deformation of the landslide. Results show that the landslide, whose slip surface lies permanently below the water table, is unaffected by rainfall, and slips in pulses which could be significantly enhanced by future seismic loads.

EFFECT OF SEISMIC DISLOCATIONS ON DEVELOPMENT OF EARTHQUAKE INDUCED LANDSLIDES

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The earthquake induced landslides are one of the types of seismic dislocations. Therefore, along with traditional methods of slope stability analysis, the study of earthquake induced landslides should include the estimate of the effect of the dynamic factor at seismic impact as well as that of the other types of seismic dislocations on the slope stability.
Studies in the Gissar village area (Tajikistan) using traditional methods to estimate the slope stability have evidenced no landslide danger. However, in the 1989 Gissar earthquake has triggered four seismically-induced landslides. The field studies the said landslides in the epicentral zone of the 1989 earthquake has demonstrated that the catastrophic slope movement had been preceded by:
- the formation of a system of seismic ruptures which have disturbed the slope mass continuity;
- liquefaction of heavily wetted loesses sensory to dynamic effect of the slope racks.
Both the physical modelling and mathematical simulation have enabled one to specify the causes and mechanism of development of seismically-induced landslides in 1989.

NH3 Earthquake risk mitigation (co-sponsered by SE)

06 Efficiency of building codes in the mitigation of the vulnerability

Convener: Petrini, V.
Co-Convener: Pujades Beneit, L.G.

NATURAL FREQUENCIES OF STRUCTURES BASED ON SIMPLIFIED IN SITU MEASUREMENTS

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The recent development of digital accelerometric instrumentation which allows a simple utilization, processing and interpretation of results, has permitted to launch a campaign to determine natural frequencies of vibrations of a large variety of different types of structures.
The measurements of ambient noise, that excites the structures, are made in different locations with a single 3-D instrument, and natural frequencies corresponding to the lowest modes of vibration, and their damping characteristics are easily identified.
Over 250 structures, among which are included buildings of different types and heights, bridges, old monuments, elevated water tanks, etc., were already tested, giving rise to a databank of information. To illustrate the interest of the data, a few examples of correlation of frequencies with geometric properties of structures are given.

EMPIRICAL DETERMINATION OF BARCELONA'S BUILDINGS NATURAL PERIODS BY USING BACKGROUND CULTURAL NOISE

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For structural design purposes, seismic codes specify formulas to estimate fundamental vibration periods of the buildings. It is important to adapt these empirical formulas to local constructive characteristics where will be applied. In Barcelona, Spain, we are performing seismic risk studies. An important input for a correct seismic risk assessment are the fundamental periods of the buildings. We have used background cultural noise as a source of excitation and we have recorded the building's response. The records have been taken in the uppermost part of the buildings. Our goal is to obtain an empirical formula linking fundamental period to some building's characteristics like constructive typology, dimensions, number of stories, height and others. We present preliminary results obtained from the measurements performed in more than 50 buildings corresponding to the main constructive typologies of Barcelona.

PROBABILISTIC APPROACH TO BUILDING CODE CONSTRUCTION.

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Design seismic forces depend on peak ground acceleration values (PGA) and on shape of design spectrum (DS) curve dictated by Building Codes.
Underestimation of PGA or wrong evaluation of DS shapes may cause great damage of structures. These characteristics strictly depend on earthquake magnitude and distance, as well as on regional and local geological conditions. At present there is no doubt that, instead of standard DS curves, it is necessary to construct so-called *"site-specifics"* design spectra reflecting influence from different magnitude event at different distances that may occur during the construction life period.
Probabilistic seismic hazard assessments in terms of ground motion Fourier and response spectra allow us to account for both regional features of seismic waves excitation and propagation, as well as local geological conditions.
It is posible to construct Design Spectrum curves for different return period (probability of exceedence) considering ordinary, public and critical structures. In this paper the comparisons between probabilistic "region & site-specific" and standard Design Spectrum curves are shown for territories characterized by different seismicity and tectonics: the South Caucasus (Armenia, Spitak) and Turan Plate (Central Asia, Gazli).

SEISMIC RISK STUDIES IN BARCELONA, SPAIN

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A methodology to evaluate the vulnerability and seismic risk of existing buildings in an urban area, within a probabilistic scheme, is developed. It uses numerical procedures to evaluate the non-linear seismic behaviour of structures, on an optimized sampling method and probabilistic models for the description of the obtained results. This method provides occurrence probabilities for different damage levels of the structures, corresponding to a given exposure period. The problem is also analyzed from an economical point of view: annual losses and minimum earthquake insurance taxes are evaluated. Finally, the proposed method is applied to the assessment of the seismic risk of the Barcelona city, Spain, where most of the existing buildings are of unreinforced masonry or non-ductile reinforced concrete.

COMPARISON OF LOSSES BEFORE AND AFTER SEISMIC RESISTANT CODES: APPLICATION TO AN URBAN AREA

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Earthquake losses affecting a given stock of buildings in an urban area are analysed estimating the probability distribution of losses. A comparison of losses is made for two categories of buildings: (i) the ones constructed before the existence of seismic resistant building codes and (ii) the others constructed after their implementation. Probabilistic methods for evaluation of seismic losses are used taking into account both (i) the seismic hazard in the area and (ii) the seismic vulnerability and fragility of the existing building stock under consideration. The probabilistic distributions of hazard and vulnerability are convolved and weighted by spatial distribution of building inventory. Hazard estimation is based on a standard approach involving the evaluation of a seismic source model, the recurrence model and the attenuation of macroseismic intensities taking into account local soil geology. Vulnerability (mean damage ratio) for different typologies that take into account the age, type of construction and height, was modelled as a function of the seismic coefficient: five typologies before the first seismic resistant code, two after its implementation and two after the application of the most modern seismic code. For each typology, a mean damage ratio, function of seismic coefficient and macroseismic intensity was adopted. For each typology a lognormal distribution was considered to characterize the observed randomness of damage values, given the occurrence of a macroseismic intensity (fragility. The probability of losses is obtained for several reference time intervals by convolving hazard and fragility distributions. To illustrate the developed method, application to different parishes in the city of Lisbon is made. For each parish the soil condition and the distribution of building types is known. The probability distribution of losses is evaluated for individual parishess or groups of parishes taking into consideration the analysis of uncertainties of the most important parameters.

NH3 Earthquake risk mitigation (co-sponsored by SE)

07 Seismic microzonation in urban areas

Convener: Roca, A.
Co-Convener: Oliveira, C.S.

EUROSEISMOD LESSONS FOR MICROZONING STUDIES

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EUROSEISMOD, a European project gathering 16 teams from 6 countries, includes as one of its major aims the test of various routine or state-of-the art methods for site effect analysis, to be used in particular in microzonation studies. This presentation will focus on the main lessons of this project.
Based on data from a very well known test-site located in the Mygdonian graben 30 km east of Thessaloniki, as well as on a few other sites, a thorough comparison was performed on various methods proposed to infer site amplification functions from instrumental recordings: the main conclusions will be presented, especially those concerning the so-called "Nakamura's" technique.
A benchmark test was also organized to compare various modelling techniques providing numerical estimates of site effects. The results of 1D linear, 1D linear equivalent, 1D non-linear, and 2D linear models will be presented, through a comparison of their respective estimates of "engineering" parameters such as peak or rms acceleration, average horizontal spectral amplification, and duration. The effect of input parameter uncertainties was also addressed through Monte-Carlo analysis.
Finally, as the project also includes partial microzoning studies in various cities (Lower Tagus area, Barcelona, Nice, Grenoble, Liege, Benevento and Thessaloniki), several examples will be presented in order to support a proposal for a microzoning methodology.

SEISMIC HAZARD ASSESSMENT OF THE TERRITORY OF LENINAKAN (NOWGYUMRI,REPUBLIC OF ARMENIA) BY MEANS OF THE METHOD OF HIGH-FREQUENCY MICROSEISM REGISTRATION

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After the disastrous Spitak earthquake, which took place on December 7, 1988 (M=7.0), the problem of seismic microzonation of the territory of Leninakan and neighbouring settlements arose. We had set a task - to draw up a seismic hazard map for the territory of Leninakan by means of high frequency microseism registration only. Observation stations, the total number of which was about 300, were chosen proceeding from the degree of building destruction, and not from the engineering-geological conditions of the given territory. Thus, they spread all over the town and neighbouring settlements. With the purpose of evaluating the Spitak earthquake intensity in Leninakan macroseismic investigations were carried out. The degree of damage of buildings and constructions was evaluated according to MSK-64 scale. The earthquake intensity in the town was equal to 8,9,10. We composed the seismic hazard map of the territory of Leninakan by means of the method of high-frequency microseism registration and compared with the 1) map of the Spitak earthquake intensity in Leninakan drawn up according to macroseismic data; 2) map of seismic microzonation of the territory of Leninakan drawn up by means of the complex method. Now it is safe to assert that the composed by us map has justified itself, as the distinguished zones of potential seismic intensity turned out to be quite corresponding to the areas of display of analogous seismic influence intensity. In fact, reliability of the proposing method for the given territory is proved by practice.

STUDY OF SITE EFFECTS IN THE AREA OF NOCERA UMBRA (CENTRAL ITALY) DURING THE 1997 UMBRIA-MARCHE SEISMIC SEQUENCE

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The town of Nocera Umbra and neighbouring villages were severely damaged by the September 26, 1997 earthquake at 09:40 (GMT) and its largest aftershocks. In order to investigate the role played by geological conditions and topography on the level of damage, 5 seismic portable stations were used to monitor 8 sites. The studied area includes the transition zone from the Recent sedimentary filling of the Topino River valley and the outcropping unit of Umbria-Marche carbonatic sequence, which constitutes the hill where the historical centre of the town stands. More than 300 three-component recordings were selected to quantify the variation of ground motions recorded by the stations. All the analysis methods (spectral ratios using bedrock representative motions, and horizontal-to-vertical spectral ratios for both ambient noise and earthquakes) provide consistent results. In addition to the expected amplifications on soft sedimentary bodies, peculiar site effects due to topographic irregularities have been quantified.

PRELIMINARY MAP OF SOIL PREDOMINANT PERIODS IN BARCELONA BY USING MICROTREMORS

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In order to evaluate soil effects in the urban area of Barcelona, the Nakamura's technique has been used to estimate the predominant periods of soils. The measurements were performed at 200 sites, by using an accelerograph and a velocimeter. Predominant periods greater than 0.8 s are obtained in areas with consolidated sediments, named "Tricicle". Values in the range between 0.5 and 0.9 s are obtained for Llobregat deltaic deposits. On the other hand, Besòs deltaic deposits present higher periods than Llobregat delta and in some zones surrounding the outcrop rock, predominant periods between 0.10 and 0.40 s are observed. In the outcrop areas we obtained periods lower than 0.10 s. In this work, the resulting preliminary map of predominant periods is presented. In some districts, the evaluated predominant periods show a reasonably good agreement with the geological typologies and the sediment thickness; other factors may affect the results in other sites.

SEISMIC ZONATION AND ACTIVE TECTONICS OF THE URBAN AREA OF FLORENCE (ITALY).

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The city of Florence has a concentration of cultural and artistic partimony unique in the world. For this reason it has a great 'exposition'. In order to analize the seismic risk of the urban area of Florence, we have performed a multidisciplinar study. In particular, studying historical seismic sources and reelaborating local macroseismic intensity on the aid of specific algorithms, we realized an example of seismic zonation for the city of Florence relatively to the shocks of 18 May 1895 and 29 June 1919. Datas are implemented by studies at different scales of the active tectonics and active faults of the sourroundings of Florence. Furthermore, also historical evolution of the city has been examined and integrated in this study. Such an interdisciplinary approach is necessary because of the rich artistic patrimony of the city, where 'vulnerability' varies from zone to zone.

SEISMIC MICROZONATION IN GRENOBLE (FRANCE)

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The earthquakes in Mexico (1984) and Kobe (1993) showed that the damages observed on buildings can vary significantly in very short distances. As there is no evidence that these spatial variations are due to differences in structure resistance we think that there is a difference in the ground motion. The problem in urban area is that, most of the time, the mechanical characteristics of the soil are poorly known and that the seismic noise level is high. Then, one have to develop new procedure to determine seismic risk in urban areas.

In this aim, we ran an experiment in the town of Grenoble (France) for 10 month between april 1995 and january 1996. We installed 10 stations in 15 sites. We recorded 28 events with magnitude from 1.8 to 8 with epicentral distances from 10km to several thousands. The recording was continuous to record all the events.

We first use the spectral ratio with a reference station (CSR) to obtain the transfer function of the site at some points. Then, we used the horizontal over vertical spectral ratio calculated with noise records (HVNR) to make a map of the frequency of amplification in the whole town. Last, we used the empirical Green's function method to try to determine the effect of strong motion by using small events.

All the results are very coherent and we can propose a procedure to make a microzonation of urban areas, by using successively these methods.

COMPARATIVE STUDY OF MICROTREMOR ANALYSIS METHODS

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During a multidisciplinary microzonation pilot project in the city of Heraklion (Crete, Greece), microtremor data were collected near exploratory boreholes specifically designed for the purposes of the project, over a period of 5days, for 4 h/day at 125Hz (continuous recordings). The data were analysed with the SSR and H/V Ratio techniques, using the standard FFT (applied to long data series) and a Multi-variate Maximum Entropy (MV-MAXENT) spectral analysis method. Both techniques, implemented with both spectral analysis methods, identify the same major resonance frequency band, albeit with different amplification levels. The MV-MAXENT however is effective in handling short data lengths while yielding high resolution spectra and addressing several shortcomings of the conventional FFT (windowing, zero padding etc.). Thus, it yields competitively similar results, with only a fraction (a few minutes) of the data required by the lower resolution (FFT) method and appears to be a powerful tool for site effect investigations. Moreover, the results of both microtremor-based techniques are consistent and remarkably similar to the results of microzonation methods that require (expensive) borehole data.

SEISMIC ZONATION OF BARCELONA BASED IN PRELIMINARY SITE SPECIFIC RESPONSE SPECTRA

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The city of Barcelona is located at the Mediterranean coast, on the pediment of the Catalan Coastal Ranges. Different materials can be recognised: Paleozoic and Tertiary materials, Pleistocene terrains composed of thin consolidated sediments, and thick Holocene deposits from the Besos and Llobregat rivers.To take into account possible local effects due to the presence of sediments, seismic response of several sites in different districts have been computed. For these sites an interactive data base has been implemented with the usual geotechnical parameters obtained from drilling for building and infrastructure. After a review of published empirical correlations between geotechnical and dynamical parameters, the most adequate relation to the soil conditions of the zone has been used. An estimation of the depth of the Paleozoic basement has been obtained from an inversion of a detailed gravity survey. Future dynamic tests and geophysical prospection will contribute to improve these values.An input motion of 0.04 g has been applied according to the value considered in the Spain Seismic Code (NCSE-94). Transfer functions have been computed for all the sites using a 1D equivalent-linear code. Great amplifications rising values of 4 appear for periods less than 1.5 s. In particular the highest amplifications have been obtained at high frequencies near to 10 Hz in the districts characterised by thin deposits. Preliminary site specific response spectra characterising different zones of the city are proposed.

SITE EFFECT DETERMINATION IN NICE, FRANCE (GEMITIS PROJECT)

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Although French Riviera has a rather moderate seismicity rate, a strong seismic event is expected mainly from Genova Gulf (M=6, 30 km far from seashore). As CETE Méditerranée is based in Nice and thanks to our important geological knowledge of the city soil, it was decided to make of our own town, our first experimental field for seismic hazard assessment. Hence, as concerned with site effect, different experimental and numerical methods are used on same sites. As for many other towns, the more densely populated districts of the city lay over alluvial fillings. A first survey (1984) allows to determine regional hazard and to recognise several geotechnical areas that might have different response to earthquake. Then, during one year (1992) seismicity was recorded on 4 sites where seismic amplification could occurred. Indeed, above the main alluvial filling, spectral amplification reached 20 for low frequency as compared to rock station. Transfer function are very interesting for it shows that soil frequency and amplitude response is totally linked to alluvion depth. The present installation of 5 accelerometric stations approximately at the same sites should answer to numerous questions concerning linearity of site effect if a strong motion is recorded. Beside earthquake record, microtremor techniques were also intensively explored. Background noise stability was studied both on time and on spatial domain. It allowed to verify spectra variations during the day, but the surprising stability of horizontal to vertical spectral ratios in time. The ability of this ratio to deliver resonance frequency of soil was also demonstrate. Results were plotted as maps of frequency and relative amplification. Numerical 2D simulations are also performed over alluvial filling thanks to CESAR-LCPC code which is based on finite and boundary element method. Finally all techniques ability will be evaluated and site effect will be more described in Nice.

MICROZONATION OF THE LISBON TOWN: A THEORETICAL APPROACH

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In areas with low seismicity it is very difficult to implement microzonation techniques based on natural seismicity. Also, for urban areas, it is not easy to perform seismic experiments. Only a few methods can be easily implemented as microtremor measurements or theoretical approaches. In order to estimate the seismic behaviour of the Lisbon town, a theoretical 1D linear approach is undertaken for the entire town. Geological profiles have been performed, along the east-west direction, 500 meters spaced. These profiles were based on the existing geological map, scale 1:10 000, and complemented with new information collected from recent geological and geotechnical boreholes. The physical parameters introduced in the theoretical model were obtained from (i) specialised literature, (ii) seismic experiments and (iii) laboratory tests. These results are presented for the northeast part of the town and compared with other microzonation maps obtained using (i) microtremors measurements and (ii) impedance contrasts.

CARACAS (VENEZUELA) SITE EFFECT DETERMINATION WITH MICROTREMOR

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Caracas 1967 earthquake caused heavy damages to multi-story buildings. In 1995, 184 microtremor measurement points were performed over the city. Measurement grid was more or less dense and covered the main part of the alluvial basin as well as surrounding rock basement. For each point, horizontal record spectrum was divided by vertical one. Then the strongest value of this ratio (A) was kept as well as the frequency (Fo) where it occurs. Spatial interpolation of A and Fo were performed between all points of Palos Grandes district. A map was plotted representing a single surface where Fo is relief and A is colour gradation. Alluvion depth (H) map can be compared with this result. Damaged buildings are plotted on the same map. Fo (relief) decreases until 0.6 Hertz when alluvion depth (H) increases. Fo values fit with frequencies previously predicted from computation and with 1967 earthquake observations. The more, interpolation surfaces show that amplification (A) is very low above rock but is maximum on the south part of the basin. Now main damages of the town occurred in this part : 4 high buildings collapsed. The estimated natural frequency of these buildings were around Fo. Graphics showing H, Fo and A evolution through basin were composed. Links between all these values are noticeable. Fo is claimed to be very similar to resonance frequency of soil. As for A, it reveals to be a fairly relevant sign of damage seriousness. Microtremor technique is an economic tool and allows measurement grid as dense as desired. H/V ratio processing followed by interpolation of maximum values provides precise and useful information about expected site effect.

APLICATION OF DYNAMIC RESPONSE ANALYSIS OF BUILDINGS FOR THE SEISMIC RISK ASSESSMENT IN ALMERIA CITY.

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In general, the dynamic behavior of building structures under strong motion is depend on the structural characteristics, for example, building material, constructed age, foundation type, building story and dimension etc. and also the characteristics of input strong motion to the building. Each building has a natural period which is depend on the structural characteristics. Usually, each site where some buildings were constructed has a predominant period which is depend on the uppermost soil condition, for example, the stiffness and depth of uppermost soil layer, respectively. Even if the uppermost soil condition is not so soft, basically, the relationship between the natural period of building and the predominant period of surrounding uppermost soil condition is very important to evaluate the earthquake damage for the buildings. So we have performed to estimate the natural period of existing 23 buildings which have the stories from 4 to 10 in Almeria City using microtremor observations at the top of buildings. These buildings have different characteristics respectively, but, in this research, we are thinking that one very important index of building characteristics is the building story. The relationship between the building stories and the natural periods is very linear and clear. The result shows : $T=0.048N$ in lateral movement and $T=0.047N$ in torsional movement, where T is the natural period in sec., and N is the building story from 4 to 10. After we get these results, we have tried to calculate the dynamic behavior of buildings using the response analysis of 1-DOFS Model, considering the different uppermost soil conditions. We would like to show the result of response analysis in order to assess the seismic risk in Almeria City.

GRAVITY ANOMALY MAP OF BARCELONA AS A TOOL FOR DETERMINING THE STRUCTURAL FRAMEWORK AND DEPTH TO BASEMENT IN RELATION TO SEISMIC MICROZONATION OF AN URBAN AREA

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Barcelona is situated over colluvial and alluvial deposits between Llobregat and Besos River deltas and these materials overlay Pliocene marls and the Hercinian basement. In the scope of a project for the evaluation of the seismic hazard of the city of Barcelona, sponsored by the city council, several geological and geophysical studies have been carried out with the aim to evaluate local conditions that would modify earthquake response.

A Bouguer gravity anomaly map of Barcelona was produced by the compilation of 935 gravity stations, with coverage throughout the city and surroundings of 1 station/km2. New gravity stations are being surveyed over a high precision network to perform a 200 m grid interval. From the inverse solution of the residual gravity anomaly, depth to basement and the structural framework have been determined, in spite of the lack of subsoil control data. This information has been useful for assessing the earthquake hazard at local scale.

THE INFLUENCE OF THE EXPERTS OPINION IN MICROZONATION STUDIES

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Recently a qualitative microzonation study has been completed for the city of Basel. The study includes the mapping of the geological and geotechnical soil conditions which are known from over 2700 shallow wells. This comprises also detailed lithological descriptions of the cores, thicknesses of the strata, groundwater data, and SPT measurements. Measurements and interpretations of ambient noise and their comparison with the local geological information lead to a characterization of the different soil types. The microzonation is performed by means of a qualitative rating scheme that takes into account the influence of seven characteristic parameters of the local soils which can be the cause of amplification of ground motion during earthquakes. Four parameters account for the influence of the Quaternary gravels. These are the consolidation of the gravels, the type of the Quaternary sediments, the thickness and the lateral variations of the thickness. A fifth parameter considers the potential of liquefaction. Finally two parameters account for the influence of the Prequaternary sediments and of the Rhinegraben master fault. The original weighting scheme has then been analysed by four experts, and each expert proposed a new scheme for the microzonation, which is also based on the seven parameters. The different rating schemes and their effects on the microzonation are discussed in this contribution. Even if there are large differences in the weighting of some of the parameters, the overall features of the different microzonation maps remain stable.

EVALUATION OF SITE EFFECTS IN VOLVI BASIN (GREECE) FROM EXPERIMENTAL DATA AND MODELING

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The results of amplification estimates due to site effects, as obtained from observed data and theoretical modeling, are compared. The data come from the Volvi basin, a test site located in Northern Greece near the city of Thessaloniki (EUROSEISTEST). We calculate the synthetic seismograms (SH and P-SV waves) for a 2D section of the target area between the Profitis and Stivos villages, where the recording stations are located. The hybrid technique employed for these computations couples the modal summation and the finite difference methods. Both in time and in frequency domain the agreement between our simulations and the observed data is satisfactory. The few observed discrepancies are very probably connected to the still limited knowledge and estimates of the parameters necessary to define the source, the propagation path and the 2D model in the hybrid technique.

SEISMIC MICROZONATION IN PREADRIATIC URBAN AREAS OF ALBANIA

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Based on seismic microzoning studies carried out, during last 15 years, in Preadriatic area of Albania, for many important inhabitated centers and cities(as Vlora, Durres, Shkodra, Fieri and Tirana city) , a comparison of different approaches with experience gained by past and recent earthquakes is shown. Some special case studies are of interest, taking into account the occurrence of recent earthquakes (Tirana & Shkodra case studies) and those of the past(Durres , Fieri & Vlora case studies).On the other hand based on seismic hazard maps compiled at local scale, the implemetation of outputs of seismic microzoning studies in physical and urban planning of some important towns (as Vlora, Durres, Shkodra, Fieri) and Tirana city and for the improvement of Albanian seismic building code, are presented..

EXPERIMENTAL SITE EFFECT EVALUATION IN URBAN AREAS OF THE UMBRIA AND MARCHE REGIONS (ITALY)

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After the 26 september 1997 Central Italy earthquake ($M_L = 5.9$) the Italian Civil Protection Department issued a seismic microzonation project. Its goal is to perform detailed investigations on some of the heavily damaged localities (Fabriano, Nocera Umbra and Sellano) with the aim to provide guidelines for urban planning and building retrofit.
In this framework a special task group devoted to site effect evaluation (Umbria Marche Site Effect Group) has been set up. This group installed three temporary seismic arrays with 54 sites monitored in the urban areas of the above mentioned localities, recording at least 20 events with magnitude up to 4.4. The preliminary results presented concern empirical transfer function evaluations based on spectral ratio technique. Reference site and single site approaches were used both for earthquake and noise recordings.

2-D STRONG MOTION SIMULATION FOR MICROZONING OF BUCHAREST

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The strong intermediate-depth Vrancea (Romania) earthquakes represent the main seismic source that has to be taken into account for microzonation purposes of Bucharest that, due to its poor soil conditions, could suffer serious damage because of the severe local site amplification. The realistic modeling of ground motion is made computing the seismic input for the target area of Bucharest considering a 2-D cross-section profile by means of a sophisticated hybrid technique, that combines modal summation and finite difference scheme. As seismic source we consider two strong Vrancea quakes (August 30, 1986, M_w=7.1, and May 30,1990, M_w=6.9). The simulated signals are analyzed against the few available instrumental records. The main features of the local response simulated under the mentioned conditions are similar to the observed ones. We see how this technique can lead to a proposed microzonation of the city of Bucharest. For the complete microzonation of Bucharest the computation will be extended to a set of cross sections that cover the whole area of the town and to a set of source parameters of strong Vrancea quakes.

DETAILED SEISMIC MICROZONING OF ALMERIA CITY USING GEOTECHNICAL INFORMATION AND MICROTREMOR OBSERVATION

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The importance of seismic microzoning and seismic risk assessment is increasing in earthquake prone area of the world for earthquake damage reduction. We have engaged in detailed research on seismic microzoning and seismic risk assessment in Almeria City since 1996. This detailed research is composed of several different works as followws. (1) Geomorphological Investigation : A landform classification map is developed by analysing aerial photos and large scale topographic maps. Since each landform is composed of different materials, it represents the uppermost part of the soils. Some geologic cross-sections are compiled from bore hole records in order to examine the deeper part of the soils.(2) S Wave Velocity Prospecting Test : S wave velocity prospecting tests are experimented at several sites. These results are usefull for understanding the uppermost soil characteristics and are used for soil classification. (3) Microtremor Observation : Microtremore observations are densely carried out in the research area. These result will be used in the evaluation of dynamical ground properties, for example, predominant period and amplification factor and will be used in seismic microzoning. (4) Seismic Strong Motion Observation : Seismic strong motion observation sites are located at four sites in the research area where are different soil condition, especially, one of them is located at hard rock site. These strong motion records are compared with each other to recognize the difference of ground shaking characteristics. (5) Integration for Seismic Microzoning : Detailed seismic microzoning is carried out by compiling the results of (1) - (4). As a result, the research area is divided into several districts which have identical characteristics of dynamical soil properties, respectively.

The Earthquake Sequence of Events During the June-October 1997 Crise in the Azores Observed under Different Soil Conditions

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Abstract

An earthquake sequence of events occurred in the Azores since 27 June 1997 and lasted until mid October. The main events were recorded in a few strong motion instruments recently implanted in the region.
During the three and half months of activity 64 earthquakes with epicenters in the ocean near the Banco D. Joao de Castro, between the islands of Sao Miguel and Terceira, were recorded in 3 to 5 stations in those two islands, producing 99 records with 3 components. Maximum local magnitude was of the order of 5.5 and epicentral distances, to the stations, range from 30 to 120 km. Peak ground accelerations range from 0.5 mg to 50 mg, depending on the epicentral distances and on the soil type. Soil properties are behind the large differences (twice in amplitude) between ground motion recorded at a location within an old crater and another at its borders, two hundred meters away.
The present paper presents the records obtained in the crise and tries to explain the most important features observed at the different locations.

REALISTIC MODELLING OF SEISMIC INPUT IN URBAN AREAS: A UNESCO/IGCP PROJECT

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The accurate study of geological and site effects on seismic ground motion and their realistic modelling addresses the problem of pre-disaster orientation: hazard prediction, risk assessment, and hazard mapping. The major scientific problem is to handle realistic models on a very detailed level. We can reduce loss of life and property damage by highly detailed, specific prediction of seismic ground motion. To map seismic ground motion we do not have to wait for earthquakes to occur in likely focal regions and then to measure ground motion with an extremely dense set of recording instruments; instead we can compute immediately these seismograms from theoretical considerations. This database can be updated continuously incoming new experimental data. The plan of the UNESCO/IGCP Project "Seismic Ground Motion in Large Urban Areas" includes a broad spectrum of seismic hazard levels that require different administrative, politcal, scientific efforts to reach a satisfactory preparedness (Antananarivo, Bangalore, Beijing, Bucharest, Budapest, Catania, Delhi, Kathmandu, Ljubljana, Mexicali, Mexico City, Naples, Rome, Santiago de Chile, Santiago de Cuba, Silistra, Sofia, Thessaloniki, Tijuana, and Zagreb). The project, the methodology followed for the simulation of ground motion and the results obtained in several cities are illustrated, including comparisons between the outcome of simple and very sophysticated approaches.

PROBABILISTIC MICROZONATION OF URBAN TERRITORIES

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The problem of accounting for local soil effect on earthquake ground motion is especially urgent when assessing of seismic hazard -- recent needs of earthquake engineering require for including effects of surface geology into hazard maps. When evaluating of seismic hazard, it is necessary to account dangerous earthquakes of various magnitudes that may occur at different distances. Characteristics of soil response strictly depend on ground motion peculiarities, and these parameters in seismic hazard calculations must be considered as random variable and evaluated jointly with parameters of ground motion. Recently developed by authors method of seismic hazard calculations allows to take into account soil response both in determenistic and probabilistic forms, and to create hazard maps involving influence of local soil conditions using soil/bedrock spectral ratios. Probabilistic microzoning maps may be constructed by calculation of "absolute intensity" instead of determination of "intensity increments" relatively to "reference site". On example of probabilistic microzoning of city of Tashkent we shown that the configuration of zones with the same probable MMI intensity (ground motion parameter) may be different (meaning both absolute values and contours of isoseismals) when considering various return periods (probability of exceedence).

SITE EFFECTS IN THE CITY OF THESSALONIKI (GREECE): ESTIMATES FROM DATA AND MODELLING

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In the present study the site effects in the city of Thessaloniki (Greece) are estimated using both an experimental and theoretical approach. The experimental techniques are applied to a set of observed accelerograms. The technique of Standard Spectral Ratio (*SSR*) is applied to a reference station located on rock, while the *H/V* Spectral Ratio technique is used both with earthquake records (entire length including P & S waves) and with recorded noise. The results from all previous methods are compared in terms of predominant frequencies and amplification levels. The fundamental frequency is identified by all methods, though the average amplification level is generally underestimated when the *H/V* spectral ratio techniques are used.
For the numerical approach, we construct complete strong motion synthetics using the modal summation method, up to frequencies of 10 Hz, for the *P-SV* waves. As input, four point sources are used, located at different distances and azimuths from the stations. Ratios of response spectra of the local 1-D over the regional 1-D seismograms are calculated. The mean spectral amplifications obtained, are compared with the experimental ones.

MICROTREMOR ANALYSIS TO CHARACTERIZE SEISMIC WAVE ATTENUATION IN THE CITY OF BARCELONA

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Microtremors are generated by the presence of short period seismic noise, and they consist of a mixture of surface and body waves. The surface sources of this ambient noise are of different origins: traffic, factories, cultural activity, etc. Microtremor recordings usually present an average amplitude that is constant with time, but sometimes interferences caused by specific easy to find sources located near the recording instrument are observed. These small events are produced, as an example, by the passing of a person or vehicle, and we will try to use them in order to characterize the capability of the medium to attenuate seismic energy. In this study, the parts of the records that present high amplitudes are analyzed, and the amplitude decays are characterized by a quality factor Q. Preliminary results for different zones of the city of Barcelona are presented. They show the ability of this method to characterize the attenuation of the different soil typologies.

ESTIMATION OF THE SYSTEM FUNCTION OF SOILS USING MICROTREMORS

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The use of microtremors to characterize soils using the methodology proposed by Nakamura in 1989, has been a topic of microzonation studies for many years, due to its rapidity and low cost. This method allows to obtain accurately the resonance frequency of a given sedimentary layer, but it fails to predict the amplification at the resonance frequency. In this study an improvement of the Nakamura's spectral ratio (horizontal versus vertical components) is proposed so that the obtention of the predominant periods and amplifications using microtremor measurements at the surface is allowed. Using the 3 component recordings of microtremors, it is considered that the vertical component represents the vertical tremor at the substrate, except for the presence of uncorrelated noise (W_v). The horizontal components constitute a complex signal that (except for uncorrelated noise W_x) represent the horizontal tremor obtained by filtering the movement at the substrate with the soil's system transference function H. This system function H is then estimated by minimizing the uncorrelated noises W_v and W_x. This methodology is applied to microtremor measurements in the urban area of Barcelona.

SE23 Seismic anisotropy, scattering and attenuation

Convener: Plomerova, J.
Co-Convener: Bean, C.J.

SEISMIC ANISOTROPY AND LARGE-SCALE FABRIC OF MANTLE LITHOSPHERE OF PRECAMBRIAN CRATONS

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The radial and azimuthal anisotropy of surface waves constrain the lithosphere thickness of Precambrian cratons to a maximum of about 200-220 km. While the anisotropy within the lithosphere is well developed, below it the seismic anisotropy is very small. Both the surface and body waves indicate dipping anisotropic structures in the mantle lithosphere which may represent remnants of accreted pieces of ancient oceanic lith osphere and paleosubductions inferred also from dipping seismic reflections extending into the mantle. An interpretation of the observed surface-wave anisotropy results in a model of olivine petrofabrics with a-c foliation plane, characterized by the high est P velocities and a subparallel polarization of the fast split shear waves. The foliation planes dip steeply beneath the cratons, compared to modest dips beneath the Phanerorozoic regions. The steep orientations of the foliation planes mean that a major part of the subcrustal lithosphere of cratons was not formed by the conductive cooling mechanism which would produce subhorizontal orientations of the olivine a-axes and the a-c foliation planes. Though the horizontal resolution of surface-wave studies is limited to 500-1000 km, the radial anisotropy indicates that the Precambrian mantle lithosphere extends beneath many Phanerozoic orogenic belts. With a dense spacing of seismic stations, the anisotropy of body-wave velocities provides a good resolution f or identification of boundaries of lithospheric blocks with different fabric orientations. By inverting shear-wave splitting parameters, e.g. at an array of stations in Scandinavia, and studying pattern of teleseimic P-residual spheres, we are able to retri eve 3-D orientation of anisotropy within different blocks of subcrustal lithosphere with hexagonal or orthorhombic symmetry.

Body Wave Attenuation in the Crystalline Crust and Mantle from PNE Data

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Quality factors (Qp, Qs) in the crystalline crust and mantle along long-range DSS profiles have been calculated from records of refracted and reflected waves using a change of amplitude and phase spectra versus epicentral distance. It has been established that in the frequency range studied (0.5-12.0 Hz), the dependence of the absorption coefficient "K" on frequency is linear and the quality factor does not depende on frequency. In general, the Kp and Ks in the crystalline crust are practically equal, while QpGQs. Qp mean value is 180 and Qs-300. In the first 700 km of the mantle Qp increases with depth from 200 to 600. The study of Qs was carried out on a more restricted scale than that for Qp. The result indicate that with increasing depth the ratio Qp/Qs increases.

SCATTERED WAVES AS AN IMAGING TOOL

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The superposition of many scattered wavelets leads to the development of coda waves. In the absence of site reverberations, these scattered wavelets are thought to sample a large volume surrounding the source and receiver and therefore have traditionally been used to yield regional Coda Q estimates. Here we present results from a new method which allows us to localise Q variations and scatterer distributions (e.g. fault zones). The method does not require linear receiver arrays and is ideally suited to irregular source-station configurations. We test the method on synthetic data and present results from both the Long Valley caldera in Eastern California and from southern California. The techniques allow us to tomographically map both intrinsic attenuation and scattering potential.

SEISMIC ANISOTROPY IN ITALIAN VOLCANIC AREAS

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Shear wave splitting analyses have been performed in the following volcanic areas in Italy: Vesuvio, Campi Flegrei and Etna. The three areas are very different from both structural and volcanological point of view. We measured the splitting parameters by means of covariance matrix decomposition method. On Vesuvio the qS1 polarization eigendirections are aligned to the main faults system recognized on the volcano. The TD values show a lot of scattering, however the source of the anisotropic volume appear shallow. On Mt. Etna the EDA cracks model appears realized far from the active faults. Shallower sources of the splitting were recognised for the stations located near the Pernicana fault and the North-East rift. The presence of an anisotropic volume at Campi Flegrei appear less clear than in the previous areas. The qS1 polarization eigendirections appear aligned at each station, but they are quite different from one station to another. We suggest that in this area the presence of scattering bodies plays an important role in the S-wave features.

TRANSITION BETWEEN DIFFERENT DEGREES OF HETEROGENEITY BENEATH THE SOUTHERN URALS

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The seismic image recorded beneath the southern Urals during the wide-angle seismic reflection/refraction URSEIS-95 experiment is consistent with a change in the degree of heterogeneity in the upper mantle. The seismic signature observed in a densely sampled (50 m) shot gather suggest an inhomogeneous upper mantle beneath the southern Urals. The sharp decrease in reflectivity imaged is modeled by a finite difference solution of the wave equation as a sharp change in the internal structure of the upper mantle. This change is consistent with a decrease in the size and amount of heterogeneities that is most probably caused by a temperature increase. This increase in temperature induces some of the inhomogeneities to reach their melting point homogenizing the mixture. This transition from a heterogeneous to a more homogeneous mantle would cause a prominent decrease in reflected energy in the seismic section. This mapped discontinuity can be interpreted as the 8^0 discontinuity. This seismic signature is also consistent with the lithosphere-asthenosphere transition.

MEASUREMENTS OF INTRINSIC AND SCATTERING ATTENUATION AT MT. VESUVIUS

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A first evaluation of the seismic attenuation at Mt. Vesuvius, has been performed in the frequency range from 1 to 20 Hz, utilizing the shallow volcano-tectonic seismicity related to this volcano, collected in the last three years.The coda-Q as a function of the lapse time and the estimate of the direct S wave total Q allow to separate the intrinsic from the scattering attenuation. We used a modification of the approach described by Wennerberg 1993. The first results show that the scattering plays an important role in the attenuation mechanism.

VARIATIONS OF THE VP/VS RATIO AT MT.VESUVIO

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About 300 local earthquakes recorded at Mt.Vesuvio in the last 10 years were analyzed in order to define the Vp/Vs ratio. The events were gathered by digital three-component seismic station equipped with short period seismometers. The P- and S-phases time picking precision was typically within ± 10 msec. S-phases were checked by means of polarization analyses in order to avoid errors such as the presence of S-to-P conversions. More than 900 P and S travel-times were obtained and the Vp/Vs ratio was computed using a modified Wadati's diagram. A depth-dependent trend of the Vp/Vs ratio seems to affect the first 5-6 km of the crust. A maximum value of 1.98 was observed at about 2 km of depth. This features could be explained by the presence of fractures and fluids in the shallow volcanic structure as evidenced by new geophysical studies.

THERMOELASTIC SEISMIC WAVES

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A dynamic problem of thermoelasticity is considered for rheologic bodies which approximate non-elastic features of wave processes in physical media. The non-elasticity is considered by including elastic and viscous elements (connected with each other in parallel or succession way in different combinations) in a mathematical model. A rheologic equation of a generalized rheologic body has been obtained

$$P\sigma + Q\varepsilon + R\theta = 0,$$

where P, Q and R are linear differential operators with constant coefficients, and a system of equations of a combined dynamic problem of thermoelasticity has been deduced for this body. Also characteristic equations of the relaxation times and the times of aftereffect and analitical expressions for wavenumbers, which determinate the phase velocities and attenuation coefficients of thermal and thermoelasticity waves were obtained. The authors have analysed the effect of the increased temperature of the medium on the wave processes in different rheologic bodies, namely in the Voigt's, Maxwell's, Pointing-Thompson's, Lethersich's, Jeffreys's, Burgeras's, Trouton-Rankin's, Anagnosti's bodies.

THE ATTENUATION STRUCTURES OF BODY-WAVE AND ITS TECTONIC IMPLICATIONS IN TAIWAN AREA

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The seismic waveform data recorded by the Central Weather Bureau Seismographic Network (CWBSN) and Taiwan Telemetered Seismographic Network (TTSN) were used to deduce the three-dimensional attenuation structures of P and S wave beneath Taiwan. The attenuation structures were obtained by the damped least-square method from attenuation time values (t*) and the travel times. Attenuation time values (t*) were calculated from these events using a spectral decay technique. Totally, the data include 1450 digital seismograms of 102 events. The magnitudes of these events are in the range between 3.1 and 4.7. P-wave and S-wave spectra were corrected for a source spectrum of w-square model. Least-square fitting was done in the frequency range between 4 and 25 Hz. Frequencies above 25 Hz are usually avoided due to the uncertainty of instrument correction. From the distribution pattern of attenuation structures in Taiwan area, some tectonic implications will be discussed in this paper.

ACCOUNTING FOR SPATIAL DISPERSION IN SEISMIC-WAVE PROPAGATION

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To increase the efficiency of seismic prospecting through using dynamic characteristics of seismic waves, interpretational models should be chosen correct. A model of an anisotropic gyrotropic medium is shown to be a sought-for model. Gyrotropy is an exhibition of the first order spatial dispersion of elastic properties of a medium. In an anisotropic gyrotropic medium, a relation between the stresses and the strains is given by Hooke's law with additional terms proportional to strain derivatives. These terms account for contributions in a stressed state at a given point of other points in its vicinity. Thus a microstructure of the medium is taken into account. For appearance of gyrotropy, it is sufficiently if microobjects (these are microcracks, thin layers, oriented grains etc.) were arranged in such a way that the medium had no centre of symmetry (necessary condition) and had predominantly 'right' or 'left' arrangement of microobjects. In other words, in properties of symmetry the medium must be acentric and chiral. Generally, polarizations of all waves in a gyrotropic medium are elliptical whereas in a chiral gyrotropic medium there occurs a rotation of shear-wave polarization plane. To reveal the nature of the phenomenon of gyrotropy, we present now the specific model of terrigeneous rocks on a microlevel. The model has the dissymmetric microstructure. The work is supported by Russian Fund of Fundamental Investigations (RFFI) grant 97-05-65282.

CENTRAL ITALY 3-D CRUSTAL TOMOGRAPHY USING DATA FROM REGIONAL AND MOBILE NETWORKS INCLUDING 1997 UMBRIA-MARCHE SEQUENCE ($M_l \leq 5.8$).

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A 3-D crustal tomography is performed for the central Italy region using local seismicity recorded by three regional networks plus the mobile network installed during the recent Umbria-Marche sequence started on the 3rd October 1997.
The regional networks, for a total of 35 seismic stations, collected data since 1992, while the mobile network, composed of 15 stations, worked from the 19th September 1997 to the 29th October 1997.
We used the simultaneous inversion method described by Pavlis and Booker and modified by C.H. Thurber and Donna Eberhart-Phillips. This technique iteratively compute the velocity model parameters, defined to the nodes of a grid, and relocate the hypocenters, by using an approximate 3-D ray-tracing.
First we performed a synthetic test. The arrival time obtained using a known velocity model were considered as observed data, then we inverted them using a different starting velocity model.The comparison between given and computed models is satisfactory.
The region shows interesting results due to the good coverage of stations and hypocentres.

ANISOTROPY IN THE AUSTRALIAN UPPER MANTLE FROM WAVEFORM INVERSION

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The SKIPPY experiment, which took place from 1993 to 1996, has allowed the coverage of the entire Australian continent with broad band stations regularly spaced every 400 km. This dense network of seismic recorders benefits from the excellent distribution of regional seismicity surrounding Australia and provides a unique dataset for upper mantle investigation in continental arrays using surface wave data.
The waveform inversion method proposed by Cara and Lévêque (G.R.L., 1987) is well suited to investigate upper mantle heterogeneities and anisotropy beneath the Australian continent: recent developments of the method allow simultaneous processing of Rayleigh and Love seismograms, possibly including overtones, in order to obtain information about polarisation anisotropy of S waves, in addition to the SV velocity; furthermore, it is possible to combine this waveform inversion technique in a tomographic procedure which allows the azimuthal anisotropy of SV waves to be addressed. The last extension of this method has resulted in an automated algorithm, able to process in a fast way the large amount of seismological data recorded during the SKIPPY experiment. We present and discuss here, the first tomographic images obtained for the upper mantle anisotropy beneath Australia.

SCATTERING ATTENUATION AND PROPERTIES OF RANDOM MEDIA IN 3D FINITE DIFFERENCE SIMULATIONS.

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The random models most often used in scattering simulations, e.g. self-similar models, have a Gaussian probability distribution. However, analyses of sonic borehole data imply that a log-normal probability distribution may better describe the heterogeneities in the crust, at least where fractures are present. We study scattering of seismic waves by producing synthetic VSP seismograms with 3D finite difference modelling in different types of random media. The random models used are the traditional self-similar random media, i.e. fractal media with varying correlation distance, standard deviation and Hurst number, or fractal dimension, and random models generated from a log-normal distribution. The scattering attenuation is calculated by the peak amplitude method giving an apparent Q for the model. The estimated Q values are then compared with analytical expressions derived from single scattering theory. This comparison allows for a number of questions to be investigated: (1) what parameters of the random media are sensitive to scattering, (2) the minimum scattering angle present in the single scattering expressions can be determined, and (3) is single scattering a good approximation when performing scattering simulations.

A COMPARISON OF SCATTERING COMPONENTS OF SEISMIC WAVE FIELDS ON ROCKY AND LOOSE GROUNDS

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A loose sedimentary layer may be considered as a near-surface waveguide. Therefore, when the information about an initial seismic signal propagates along the layer by virtue of multiple reflections in it, one may expect that the relationship between the maximums of intercorrelation functions and the distance between seismic recorders in the group of radiuses of correlations will be different from a similar relationship obtained for rocky grounds, especially in the event that an absorption in the layer is smll, which is typical of loose sedimentary permafrost. A comparison of similar relationships, singly obtained for loose and rocky grounds at different central frequencies of band filters (those of Kaiser's) shows that the inhomogeneity of a wave field, caused by the scattering of a seismic signal by the medium of its propagation, is described by the same relationships. The most difference between relationships is observed in a frequency band of 0.75 - 1.5 Hz. But the confidence intervals equal to 0.12 (rocky grounds) and 0.15 (loose ground) overlap each other at a probability level of 0.9. Thus, one may conclude the following. First, a permafrost layer of largedetrital sediments is relatively homogeneous for seismic waves with the frequencies from 0 to 16 Hz and does not produce much effect on the homogeneity of a seismic field. Nevertheless, it does not mean that the layer does not distort dynamic characteristics of a wave field. Second, it confirms the fact that the scattering of a wave field is mostly conditioned by deeper inhomogeneities of the mediums.

COMPLEX PATTERNS OF SEISMIC ANISOTROPY IN REGIONS OF ACTIVE TECTONICS

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The accumulation of high quality broad-band seismic data is providing evidence of the usefulness of seismic anisotropy in interpreting deformational processes in the upper mantle. These data also show complex patterns of seismic anisotropy, particularly in plate boundary regions and regions of relict plate boundary structures. The complexity evident in these data can be produced by a variety of structures in the upper mantle. Patterns with azimuthal periodicity, traditionally interpreted as resulting from multi-layered anisotropic fabric, can also be produced by dipping structures and/or dipping fabric, a situation expected in convergent plate boundary regions. The juxtaposition of lithosphere of contrasting mantle fabric along major strike slip boundaries will produce complex patterns of anisotropy parameters for stations near the plate boundary. The mantle fabric produced in the shear zone separating the plates will add additional complexity in the azimuthal pattern of seismic anisotropy. Interpreting these patterns of seismic parameters requires consideration of the effects of a three-dimensional mantle fabric on wave propagation, and the arbitrary complexity introduced by the juxtaposition of relict mantle fabrics (with active mantle fabrics) along plate boundary zones. Data sets from Tibet and western North America provide examples of these effects.

SKS SPLITTING BENEATH THE BAIKAL RIFT ZONE

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SKS splitting was determinrd at 28 digital seismic stations and 35 analog stations in the Baikal rift zone and adjacent areas. We determined two splitting parameters, splitting time and fast direction, by searching for the minimum of an error function. Splitting ranges from 0.3 s to 2.1 s which could have been caused by layers of 30 to 210 km thick, respectively, characterized by 4% anisotropy. Fast directions in the inner part of the Baikal rift zone are distributed in two orthogonal directions, NE and NW, approximately parallel and perpendicular to the NE strike of the rift. In the external parts of the rift zone only the rift-orthogonal fast direction is observed. Rift-related mantle flow, that is responsible for orientation of olivine crystals, provides a plausible interpretation for the rift-orthogonal fast directions. The rift-parallel fast directions near the rift axes can be interpreted by oriented magmatic cracks in the mantle or small-scale mantle convection with rift-parallel flow. The agreement between stress estimates and corresponding crack orientations lends some weight to the suggestion that the rift-parallel fast directions are caused by oriented magmatic cracks.

FRENCH MASSIF CENTRAL: DETERMINATION AND MODELISATION OF P-WAVE ATTENUATION

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Volcanism in French Massif Central is dated at 20 Myr to 4000 years BP with a paraxismal activity during the middle Miocene time. The measurements of attenuation is helpful to understand the mechanical origin of abnormal P wave travel time in lithosphere beneath 2 important volcanoes. To estimate Qp attenuation, we used a new comparitive analyze of shape of P wave in time domain. This analyse permits to localize two regions of strong attenuation in the Devès-Velay and Cantal areas. These two abnormal regions of propagation are clearly correlated with lateral heterogeneities observed with the inversion of P wave traveltime residuals (Granet et al., 1995). Our thermomechanical modelisation using a distribution of relaxation time shows that the thermal effect can explain only 10% of the observed attenuation. Only the presence of fluids could explain the Q factor value lower than 100. The persistence of strong crustal perturbation show that these two regions were key areas for the circulation of magmas in the crust during the last volcanic events.

ISOTROPIC TOMOGRAPHIC INVERSION AND ANISOTROPIC MANTLE : WHAT DO WE MISS ?

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In the last decade, new models from regional-scale seismic tomography of the Western European lithosphere-asthenosphere system have been proposed. These models were obtained from isotropic tomographic inversion based on high resolution teleseismic experiments. However, this isotropic approximation is not strictly valid everywhere in the mantle as is clearly indicated by studies of S-waves splitting in tectonically active areas. Hence, teleseismic or local isotropic tomography alone is not able to constrain the geodynamic models deduced from imaging the velocity perturbations. Anisotropic bodies located in the mantle with the size of several tens of kilometers may significantly bias the estimation of isotropic P-wave velocity perturbations. Based on recent experiments performed in Western Europe where both velocity anomalies and anisotropic structures were evidenced independently, we will show that in some cases anisotropy-induced artifacts in the velocity models may mask important structural features in the lithosphere. Only approaches, which will address the question of estimating such possible artifacts by either the isotropic inversion of synthetics calculated for anisotropic media or "total" tomography (P- and S- isotropic images together with gravity field and seismic anisotropy) will help answer this problem.

REFERENCE MODELS OF SEISMIC HETEROGENEITY IN THE LITHOSPHERE: A 1/f-PERSPECTIVE

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Modelling and inversion of scattered seismic signals generally require some form of *a priori* information on the stochastic nature of the scatterers. For the uppermost crust such reference models of seismic heterogeneity can be established based on constraints provided by sonic logs. Sonic logs are detailed measurements of the *in situ* seismic velocity structure along boreholes. Power spectra of sonic logs universally decay as the reciprocal of spatial frequency, regardless of the petrological composition, geological age, and tectonic history of the lithologies penetrated by the borehole. A quantitative model is presented to explain this puzzling stochastic uniformity of upper crustal seismic velocity fluctuations. The impacts of this form of seismic heterogeneity on various types of seismic data are evaluated and ways to take advantage of this inherent *a priori* information are presented. Finally, the question is addressed whether and how the proposed model explaining the ubiquity and uniformity of the 1/f-noise nature of seismic velocity fluctuations in the uppermost crust could be generalised and extended for the deeper parts of the lithosphere.

TIME SECTIONS OF THE ATTENUATION DECREMENTS

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A method determining decrements of attenuation $\delta = aV$ of seismic and other waves and setting up their time sections is considered, where $a = a(x,t)$ is a linear component of absorption spectrum $\alpha(f) = a(x,t)f$, $V = V(x,t)$ - velocity of propagation of the waves, f - frequency, x and t - space and time coordinates. For this purpose the basic normalized functions are calculated by which each seismic trace is subdivided into several narrow-frequency-band components, amplitude modulation is made to increase the frequency of signals, envelopes are set up using Gilbertis transforms and then attenuation decrements are estimated for each discrete part of the seismic trace. The method has been used to prognose anomalous zones of the attenuation of seismic waves, especially those associated with oil and gas fields, areas of weakening and disturbances in a geologic section, as well as to process of the results of radiogoniometry of near-surface zones. The method may be used for studying attenuation and interpreting different types of waves in seismology and volcanology. Actual data of marine and subaerial seismic studies have been processed and interpreted. For example, in the area of the Golitsyn's structure (Black Sea shelf),Sclukhivske field (Dnieper-Donets basin) etc. where hydrocarbon deposits are known in riftogenetic carbonate sediments clear-cut attenuation decrement anomalies have been found.

AN EXPERIMENTAL STUDY OF ELASTIC WAVE PROPAGATION AND PERMEABILITY ANISOTROPY IN CRUSTAL ROCKS

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We present results from an experimental study of the relationship between elastic wave propagation anisotropy and permeability anisotropy in a shale, a sandstone and a tuff. These rocks represent a spectrum of pore/crack geometries from nearly equant pores (tuff), via a mixture of cracks and pores (sandstone) to a layered, platy fabric (shale); and a range of permeabilities spanning more than six orders of magnitude. All of the rock cores tested exhibited significant anisotropy in both compressional and shear wave velocity, varying from about 4% to over 17%. Following the velocity measurements, sub-cores for permeability measurements were taken in the maximum and minimum velocity directions. At low effective pressure, the permeability was highly anisotropic, as expected. However, as effective pressure was increased, the change in permeability anisotropy depended on the pore/crack aspect ratio, with the anisotropy being maintained in the tuff while the shale permeability became effectively isotropic by an effective pressure of 35MPa.

ANISOTROPIC TOMOGRAPHY OF LITHOSPHERE BENEATH FRANCE USING REGIONAL ARRIVAL TIMES

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This work presents a new and original study on anisotropic tomography beneath France. We used travel times of refracted regional waves to simultaneously retrieve lateral variations of seismic velocity and seismic anisotropy within the sub-crustal lithosphere. The parametrisation sheme uses a "classical" approach by dividing the 2D model in cells, each charcterised by two parameters : a mean slowness (isotropic term of slowness) and an azimuthal anisotropic term. 24968 travel times from the *Bureau Central Sismologique Français*' database have been inverted to compute both velocity and anisotropy parameters. Synthetic tests have been performed in order to validate the inversion algorithm and to verify the significance of the solution based on the available data. These tests demonstrate the reliability of our method. The velocity model obtained correlates well with the main tectonic structures in France, especially the Alps and the Massif Central. The anisotropic model puts emphasisis not only the recent Cenozoic deformations caused by the Africa-Europe (Alps) and Iberia-Europe (Pyrenean) collisions, but also reflects older tectonic structures related to the Hercynian orogeny in the Massif Armoricain, the Massif Central and the Vosges–Black-Forest region.

SHEAR WAVE VELOCITY DIFFERENCES IN AEGEAN REGION, GREECE, AS INFERRED FROM RAYLEIGH WAVE DISPERSION

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An analysis of Rayleigh waves generated by earthquakes in southern Aegean, Greece, as they have been recorded by the vertical component of the WWSSN long period seismographs of Athens (ATH), Istanbul (IST) and Jerusalem (JER), is presented in this study, in order to estimate the variation of the seismic shear wave velocity as a function of depth along specific propagation paths in the area. The analysis of the records includes digitization, analysis in the frequency domain to get the group velocity as a function of frequency, i.e.dispersion curves, and finally inversion of the dispersion curves to obtain profiles of the shear wave velocity. The earthquakes are grouped into two different groups. One, that lies with ATH and IST on a great circle which runs Aegean from NE to SW, and another, that lies between ATH and JER in order to describe variations in shear wave velocity between the inner and the outer part of the Hellenic arc.

SPACE-TIME VARIATIONS OF SHEAR WAVE ATTENUATION FIELD IN LITHOSPHERE AND ASTHENOSPHERE OF THE NORTH TIEN SHAN

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A totality of experimental data strongly support a conclusion, that in the region of Central Asia S-coda at frequencies of ~ 1 Hz is formed mainly by shear waves, reflected from multiple subhorizontal boundaries in the crust and upper mantle. This conclusion allows to study 2-D and 3-D structure of the shear wave attenuation field in the lithosphere and asthenosphere. To investigate spatio-temporal variations of this field in the North Tien Shan region we have analyzed a few hundred seismograms from local earthquakes and quarry blasts, obtained by 11 stationary and temporary stations in 1965-1995. It has been shown, that the attenuation field is rather homogeneous in low-seismicity region of the Ili depression. It is characterized by very strong heterogeneity in the region of Zailiysky and Kungey Alatau ranges, where two earthquakes with M>8.0 have occured during last 100 years. Three types of the temporal changes have been found: long-term variations, correlated with changes of the Earth's rotation speed , and also relatively short-term variations, connected with preparation for strongest deep-focus Hindu Kush earthquakes and strong shallow events in the Tien Shan region. These effects are most strongly expressed in vicinity of large deep fault zones. The attenuation field structure is essentially varied in space and time at depths less than about 280 km. The data obtained testify to an active fluids migration in the crust and uppermost mantle and their important role in geodynamical processes in the region of Central Asia.

Q AND α DETERMINATION ON OBSERVATIONS OF THE DIRECT TRANSMITTED AND REFLECTED WAVES

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From the energy conservation principle a linear equation connecting the quality factor Q, the frequency f, and time t of the propagation of the reflected or direct transmitted wave in the absorbing medium has been derived:

$$1-\left(\pi/_{2Q}\right)ft=0$$

From this equation the untraditional method to determine the parameters of the anelasticity of the Earth (quality factor Q and absorption coefficient α) by observation of the reflected or direct transmitted waves has been developed:

$$Q=\left(\pi/_{2}\right)ft,\quad \alpha(f)=\left(2/_{L}\right)$$

where L is a distance, traversed by reflected or direct transmitted wave.
The reccurent procedures to calculate the formational (layer's) parameters Q and α for a layered medium from the afore-cited formulae were also developed.
The untraditional method proposed is protected from the ambiguities of Q and α determination associated with the additive distorting effects on intrinsic Q and α by the stratigraphic filtering in the layered media, the secondary lateral waves and the curvature of the interfaces.

TELESEISMIC SHEAR WAVE SPLITTING VERSUS UPPER MANTLE HETEROGENEITY IN ITALY

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Peninsular Italy includes different tectonic provinces in the frame of the Apenninic incomplete subduction and continental collision. We investigate the deep structure and the geodynamic evolution of this region by means of a comparative analysis of seismic tomography and teleseismic shear wave splitting. Tomographic studies provide evidence in favor of a continuous subduction system beneath peninsular Italy, with evidence of a slab window in the uppermost mantle below central and southern Apennines. The shear wave splitting measurements, estimated at 35 temporary stations deployed along three teleseismic transects in northern, central, and southern Apennines (GeoModAp, E.C. contract EV5V-CT94-0464), reveal the presence of strong seismic anisotropy in the upper mantle. The anisotropic parameters appear to be related to the upper mantle structures retrieved by seismic tomography. The complex pattern of fast polarization directions found in this region of the Mediterranean is not easily interpreted in terms of main plate motions; more likely, it is strongly affected by the presence of fragmented lithospheric slabs and of asthenospheric flows induced by slab retreat processes and slab window occurrence.

ANISOTROPY OF THE P-WAVE VELOCITY IN THE AREA OF CENTRAL AND SOUTHERN EXTERNAL DINARIDES, CROATIA

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The anisotropy of P-wave velocity in the crust and upper mantle of central and southern External Dinarides was determined by considering travel-times of Pg and Pn phases recorded on local and regional seismic stations. A total of 4965 Pg and 6833 Pn arrival times from 1027 well-located earthquakes in that area were selected for analysis. The velocity representative for a given azimuth interval was determined by considering differences of travel-times and of ray-paths for all events as reported by stations within this azimuth window. The obtained azimuthal distribution shows pronounced anisotropy both in the upper crust and in the upper mantle. The crustal velocities range between 5.8 and 6.3 km/s. Minimal and maximal values are obtained for approximately ESE–WNW and SW–NE direction, respectively. For upper mantle the distribution is similar, and velocities are found between 7.5 and 8.4 km/s, with fastest waves traveling approximately SSW–NNE. The direction of low velocity is roughly perpendicular to the average direction of the pressure axis obtained by analyzing available fault-plane solutions in this area. This fact indicates that the observed anisotropy is most probably caused by the stress-induced alignment of microcracks and mineral crystals under tectonic stress.

SOME ALGORITHMS FOR CALCULATION OF SYNTHETIC SEISMOGRAMS IN ANISOTROPIC MEDIA

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The paper is dealt with different algorithms of calculation of synthetic seismograms in nonhomogeneous azimuthly anisotropic media. A common feature of all the algorithms is reduction of the 3D problem of elastic wave propagation to a series of 1D problems by means of the finite integral Fourier transform with respect to two horizontal coordinates. Different approaches to solving the 1D problems obtained in variables z and t for the fixed spatial frequencies are considered. The first approaches based on the use of the explicit finite difference method with the second order approximation and variable time step. The second approach is based on using the finite difference approximation only in the spatial variable z. The obtained system of equations is of sec ond order with respect to the variable t with the help of the orthonormal decomposition reduces to N independent Cauchy problems with zero initial data, and is analytically solved. The third approach is based on employing the Laquerr transformation with respect to the time coordinate and the finite difference approximation with respect to the spatial variable z.

TRANSIENT MOTION OF AN ELASTIC HALF-SPACE CONTAINING SMALL INCLUSIONS NEAR A FREE BOUNDARY

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Wave propagation process in a semi-infinite elastic medium with small inhomogeneities (elastic inclusions, pores or liquid-filled cavities) embedded near a free boundary is under consideration. Their sizes are much smaller than the distances between them. Material of the medium is homogeneous, isotropic and linearly elastic. Motion is created by a seismic impulse of the displacement. Its characterictic period is comparable with period of shear wave propagation between the inclusions. Direct numerical solution of the problem stated is associated with the significant difficulty for the reason of degeneration of the region. Integral equations of motion are derived by means of asymptotic methods and are suitable for the numerical solution. The displacements and the stresses are calculated numerically through solving these equations. The interaction between Rayleigh wave and the system is also considered.

ASPECTS OF PRONI-TRANSFORMATION APPLYING IN SEISMIC DATA PROCESSING

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The Proni-transformation is based on wave field decomposition into exponentially decreasing cosinusoids with parameters: amplitude, frequency, attenuation, phase. Real seismic signals can be represented as a sum of such cosinusoids rather accurately. It is suggested to use the Proni-transformation for analysis of rock physical properties and state. The technique involves determination and study of wave field high-frequency components. The components clearly reflect rock fracturing, breakdown and fluid-saturation through their attenuation. This can be explained by non-linear (square-law) dependence between seismic signal attenuation and frequency for the above-mentioned cases. This dependence is confirmed by experiment data and is based on non-elastic absorption and seismic scattering in unconsolidated rocks. Application of the Proni-transformation for real media in Siberia region shows that there is a good correlation of zones of intense attenuation for high-frequency components with tectonic dislocations and with fracture reservoir areas. The technique suggested permits to increase vertical and horizontal seismic resolution and to determine reliably boundaries for blocks of different physical properties.

A SEISMIC ARRAY ON MT. VESUVIUS

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A seismic array composed by 24 Mark L22 expanded up to 1Hz sensors (20 verticals + 4 horizontals) was installed on Mt. Vesuvius. The signals were recorded by 3 mobile personal computers. The array deployment had approximately a radial symmetry, with a three component digital seismic station (equipped with a Mark L4C 3D sensor) installed at the centre; the average distance between the sensors was about 50 meters. The array covered an area located on the south-western caldera rim, where several small scale structures have been recognized. More than 100 local and regional seismic signals were recorded. Converted and scattered phases, as well as the coda of the signals were studied with the array zero Lag Cross-Correlation technique. The waveform composition was obtained by polarization analyses both in the time and frequency domain. The correlation of the wavepackets composing the noise wavefield was also investigated to study the noise directionality. The results were compared with the ones obtained by both the recent seismic tomography experiment (Tomoves 96) and the Osservatorio Vesuviano seismic network's digital records of local seismicity. The array experiment evidenced the occurrence of ultra-micro seismicity ($M<0.5$) detected only in the array area.

GLOBAL DISTRIBUTION OF CODA-Q FACTOR

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The frequency dependent coda quality factor Qc(f) describes the seismic wave attenuation in the lithosphere due to anelasticity and scattering. Using data published in the literature on Qc(f), as determined in different areas of the world, its global distribution is presented and discussed, showing the correlation with regional characteristics: tectonic activity, geology, crustal thickness, heat flow, gravity, seismic wave velocity, etc. Maps showing the geographic distribution of Qc at 1 Hz (Q0) and its frequency dependence, as well as the Q0 isolines, are presented.

ANISOTROPY AND STRUCTURE OF THE UPPER MANTLE BENEATH THE TRANSITION ZONE OF SAXOTHURINGICUM AND MOLDANUBICUM

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The scope of our investigations is the upper mantle beneath the transition zone of Saxothuringicum and Moldanubicum in SE Germany and NW Bohemia. To resolve anisotropy and structure we use different inversions (analysis of SKS-phases, receiver functions, tomography) and seismic records from a temporary installed profile of 25 broadband stations which crossed the assumed suture zone of both tectonic units. The analysis of the observed shear-wave splitting of SKS-phases shows in general an E-W orientation of the fast axis of the anisotropic mantle material. This direction deviates only slightly from the strike of the Hercynian mountain belt and from the direction of the absolute plate motion. Indications for the transition zone come from a rotation of the fast symmetry axis from WNW-ESE to WSW-ENE when going from the southern part of the profile (Moldanu-bicum) to the northern part (Saxothuringicum) and from strong variations of the splitting parameters with respect to the azimuths of the incoming waves in the middle of the profile. The variations will be discussed in the context of a complex mantle structure such as several anisotropic layers and/or layers with inclined symmetry axes and with respect to heterogeneities. Additional insight into the structure of the transition zone we expect to get from the calculation of receiver functions as well as from several temporary installed stations in NW Bohemia. Preliminary results will be discussed.

ANISOTROPY BENEATH CALIFORNIA : SHEAR WAVE SPLITTING MEASUREMENTS USING A DENSE BROADBAND ARRAY

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We investigate the anisotropic structure beneath California, and more general, the Western United States, by performing shear wave splitting measurements on SK(K)S data recorded by over 70 broadband stations, with very dense spacing. For most stations we were able to obtain reliable measurements of fast polarization direction and delay time. Two stations (ISA and MLAC), located above a very complicated shallow velocity structure showed evidence for incoherent transverse SKS energy, possibly due to 3-D structural effects. For all other stations, we find consistent, high quality splitting parameters which do not vary significantly in fast direction with back-azimuth, although we do find variations in delay time of around .6 sec for different events for one station and for different nearby stations. The fast directions we obtain are consistent with those found by Pn studies in the area, and are also close to orthogonal to the maximum contemporary principal horizontal stress direction (World Stress Map). Previous studies have found that there is little splitting in the crust in southern California, so we interpret our results as alignment of olivine crystals in the shallow upper mantle, over a depth range of about 200 km, consistent with the shallow stress field. The variation of delay time possibly points to small-scale changes in the strength of the crystal alignment.

INTERPRETATION OF SHEAR-WAVE SPLITTING OBSERVATIONS IN THE PRESENCE OF VERTICALLY-VARYING ANISOTROPY

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We study teleseismic shear-wave splitting due to multiple anisotropic layers. As a special case, we consider smooth variations of anisotropy with depth. The model is characterized by the fast-axis directions at the top (ϕ_t) and bottom (ϕ_b) of the anisotropic region, and the total delay time (Δt). The particle motion at relatively long periods ($T/\Delta t \gtrsim 5$) is elliptical and is a function of the initial polarization direction. At shorter periods ($T/\Delta t \lesssim 1$), however, the seismogram is characterized by two distinct arrivals which are polarized parallel to the fast and slow axis directions at the top of the anisotropic region and are separated by Δt. Only the short-period results agree with predictions based on ray theory. At fixed initial polarization, the longer-period results can be described in terms of an apparent fast-polarization direction (ϕ_a) and an apparent delay time (δt_a). The apparent splitting parameters exhibit a $\pi/2$-periodicity as functions of initial polarization, similar to the two-layer case considered by Silver & Savage (1994). Assuming that $\phi_t - \phi_b < 45°$, we find variations of ϕ_a and δt_a to be smaller than 10% over most ($\approx 2/3$) of the back-azimuth range. In this case, $\phi_a \simeq (\phi_t + \phi_b)/2$ and $\delta t_a \simeq \Delta t$. The calculated apparent-splitting parameters agree well with direct measurements using synthetic waveforms.

SCALES OF HETEROGENEITIES IN THE CONTINENTAL CRUST AND UPPER MANTLE

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A seismological characterization of crust and upper mantle can refer to large scale averages of seismic velocities or to fluctuations of elastic parameters. Large is understood here relative to the wavelength used to probe the earth. In this paper we try to characterize crust and upper mantle not primarily by their average velocities but rather by random fluctuations of the elastic properties. We focus on the statistical properties of these fluctuations acting as scatterers and it becomes evident that different scales of heterogeneities prevail in different layers of crust and mantle. Although we cannot provide final models and explanation of why these different scales exist, we believe that scales of inhomogeneities carry significant information on the tectonic processes when they affect the lower crust, the lithospheric and the sub-lithospheric upper mantle. We focus on 4 different types of small-scale inhomogeneities: (1) the characteristics of the lower crust, (2) velocity fluctuations in the uppermost mantle, (3) scattering in the lowermost lithosphere and on (4) heterogeneities in the mantle transition zone.

ANELASTIC ATTENUATION IN THE NORTH OF PORTUGAL

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In May, 1997 an earthquake of local magnitude 5.4, with origin in Galiza (Lugo earthquake), was felt in the North and center of Portugal with intensity V. This earthquake and their replicas were recorded in a short-period seismic digital portuguese network, installed in the beginning of 1995. In this serie of eleven events the magnitude is equal or above 4.0 ML and in a period of 72 hours, Portuguese stations recorded more than two hundred events. This Northwestern region of Iberian Peninsula has a low seismicity: in the last fifty years, and before the events which ocurred in 1997, only ten earthquakes were recorded in this region with a magnitude equal or above 4.0. In this study we analyse coda waves of Lugo earthquake serie together with other events occurred in November and December 1995, whose epicenters are in the same area. using The method of analysis used in this work is the one which Havskov proposed (Havskov et al., 1989). Coda-Qo and the anelastic attenuation, its frequency dependence, were determined and the results were compared with the values proposed by for the North of Portugal (Pujades et al. 1990). The same calculations were done for local events in the same period (1995-1997) in order to achieve a better knowledge of anelastic attenuation for the area of the North of Portugal.

ANISOTROPY FROM GENETIC WAVEFORM INVERSION OF MULTI-COMPONENT WIDE-APERTURE SEISMIC DATA

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The determination of anisotropy parameters is essential for accurate seismic imaging and lithological identification. The inverse problem of anisotropic parameters is non-unique applying linear waveform inversion techniques. But this nonuniqueness problem can be overcomed by including data from wider angles and using multi-component data.
In this study, a nonlinear waveform inversion technique using a genetic alogorithm combined with a local optimization method is developed to determine anisotropic parameters of sub-surface from multi-component wide-angle seismic data. The waveform inversion consists of minimising a misfit function in least-square sense. Synthetic data is computed using a reflectivity method for anisotropic media. Since the misfit function for wide-angle data is non-linear, we use a genetic algorithm (GA) as a global optimization method in order to converge to global minimum. Our synthetic results show that the landscape of misfit function is flat and complex near the minimum point, and GA becomes very hard to find the global minimum. Therefore, we use a local optimization method, simplex, to search the minimum using the best model of GA as starting model. Our synthetic tests show that our approach can find the global minimum exactly with fast converge speed. We use Bayesian statistics to estimate uncertainty and resolution of final model for the real data set.

SE24 Seismic rupture processes: confrontation of observations and theory

Convener: Ihmlé, P.F.
Co-Convener: Deschamps, A.

SOURCE TOMOGRAPHY AND FRICTIONAL PROPERTIES OF LARGE SUBDUCTION ZONE EARTHQUAKES

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Source tomographic imaging is a useful tool in the teleseismic analysis of large earthquakes. We study in this way a series of large subduction zone earthquakes based on the inversion of surface wave data in the range 4-60 mHz, and of geodetic data if available. The Nicaragua 1992 (Mw 7.7) tsunami earthquake shows two distinct patches of moment release with rupture velocities around 1 km/s. The Chile 1995 (Mw 8.1) event has unilateral propagation toward the south at about 2.6 km/s, and a relatively smooth slip distribution. The Peru 1996 (Mw 7.5) tsunami earthquake displays a bilateral rupture process with variable rupture velocities in the range 1.0-2.0 km/s. We explore systematically the frictional behavior of a dynamical model of seismic rupture. We find that variations of rupture velocity among the above events can be related to variations in the frictional properties of the subduction interface. In particular, tsunami earthquakes appear to occur in regions of little background seismicity and of scarce aftershock activity. Our analysis suggests that unusual frictional properties at the plate interface, perhaps related to subducted sediments, are responsible for the slow nature of tsunami events.

MOVING WAVES OF DEFORMATION AS A MECHANISM OF SEISMIC RUPTURE PROCESS

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The long period waves, preliminaring stress drop were registrated by laser velocimeter method in shear-slip modeling experiments. Single polar wave profile were always observed after integration. The wave amplitude is reduced with distance from fault zone and became zero. Spectral structure of acoustic signal is changed from anomaly low frequency at fault to standard high frequency with distance from foci. This phenomena were observed while carrying out field experiments (rock burst). The observed long period waves in fault zone is interpreted like moving deformation waves. It is represented a contact interaction of two solid bodies at their relative motion by the scheme of contact interaction of mass-having slender deforming lines. Relationships between relative velocity and motion value of a contact surface arbitrary point and geometrical form of deformation transverse and longitudinal waves, their velocities and contact lengths are reported. Forms of longitudinal and transverse waves at displacement motion are observed on different models. Deformation wave velocity; velocity and value of displacement of a contact surface of arbitrary point in the course of moving wave of deformation are determined experimentally. Theoretically estimated and experimentally observed spectra of oscillations have been presented. Physical interpretation of observed (laboratory experiments, rock bursts, aftershocks) modulated oscillations, in the shape of interaction of elastic waves and deformation ones is given.

RUPTURE PROCESS OF THE 1996 EPAGNY-ANNECY EARTHQUAKE (FRENCH ALPS)

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Recovering the history of rupture propagation of small and moderate earthquakes is a difficult task, especially when only a few closeby unsaturated recordings are available. Based on the analysis of both clipped and unclipped signals recorded at local and regional distances, we studied the rupture process of the 1996 Annecy event, an Mw 4.9 earthquake caused by left-lateral slip on the Vuache fault in the northern French Alps.
To separate path and source effects contained in the seismograms, we used recordings of the largest aftershocks as empirical Green's functions (EGF). From the traces that were recorded on scale, we deconvolved the mainshock waveform by the EGF and retrieved the Apparent Relative Source Time Function (ARSTF) at each station. On the clipped traces, we measured pulse-width differences between the P-wave arrivals of the mainshock and of the largest aftershocks. Both types of data show evidence for a complex rupture process with at least two sub-events and for a rupture that propagated predominantly towards the south. This directivity is compared to the aftershock distribution obtained by Thouvenot *et al.* (1997), which shows that most of the aftershocks occurred to the north of where the rupture of the mainshock initiated.

STRESS AND FRICTION ON EARTHQUAKE FAULTS INFERRED FROM NEAR-FIELD SEISMIC DATA

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We investigate the space and time history of the shear stress produced on faults during recent earthquakes for which near-field seismic data are available. The stress is directly calculated from the tomographic image of slip on the fault derived from strong motion data. The results obtained show that the static and the dynamic stress drops vary greatly over the fault. The peak values obtained for most of the events studied is high and range from about 20 to 100 MPa. These high values imply that the initial stress level on the fault at the onset of rupture is high on at least a significant portion of the fault. The apparent strength of the fault before the earthquake (that is the local shear stress increase which is required for rupture) is also extremely heterogeneous. The rupture velocity seems to be inversely correlated with this apparent fault strength, the rupture accelerating over the "weak" areas of the fault and slowing down over the high strength areas. After the earthquake, the shear stress is increased over a significant portion of the fault, which corresponds to low slip regions.

ON THE INTERPRETATION OF SUBEVENTS IN TELESEISMIC WAVEFORMS: ANALYSIS OF THE DEEP BOLIVIA 1994 EARTHQUAKE

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The source process of an event is often thought to be composed of a series of subevents. Critical points in teleseismic body waves, such as peaks, coherent arrivals, are in general viewed as points in the spatio-temporal history of an earthquake. We show that these features can be interpreted as the instantaneous centroid locations of a propagating rupture front. The instantaneous centroids need not correspond with regions of high moment release, and rupture velocities may in some cases be misinterpreted. We demonstrate this point on the basis of both a subevent and a source tomographic analysis of the Mw=8.2 Bolivia 1994 deep event. The instantaneous centroid locations of peaks in the slip history correspond closely to the locations found using the subevent analysis. Especially near the middle and the end of the rupture, the instantaneous centroid locations are in regions of little moment release. We will discuss how the subevent analysis and the instantaneous centroid approach lead to dissimilar interpretations of rupture processes, especially for events with small length to width aspect ratios. In addition, we show that asperities or a rough slip distribution are not required to produce peaks or pulses in teleseismic waveforms.

WHERE WILL BE THE NEXT GREAT EARTHQUAKE

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The great earthquakes follow each other with small interval of time. The good example is the sequence of events near the Japan from 1992 to 1996. The seismic records of the previous one contains information about location of the next one. By analyzing the seismic records we have discovered that the great aftershocks occurs when the low frequency seismic wave of the main shock comes again at the Earthquakes area. These aftershocks are the earthquake induced by the surface wave of the great Earthquake. The surface wave of the great Earthquake can induce the forshocks of the future earthquake. The method of signal analysis by carrying out the construction of the seismic source trajectory have been proposed. The seismic source trajectory is the line on the map which shows the positions of the sources of the sequential patterns of the seismic signal. The trajectory of the earthquake January 15, 1993 contains the 7 patterns located in different regions: in vicinity of the epicenter, in vicinity of the source area of the earthquake February 7, 1993 (37.6N, 137.2E, Noto), in vicinity of the earthquake July 12, 1993 (42.6N, 139.2E, Okushiri),in vicinity of the source area of the earthquake October 4, 1994 (43.6N, 147.25E, Shikotan), in vicinity of the earthquake December 28, 1994 (40 5N 143.5E Sanriku) in vicinity of the earthquake January 17,1995,(34.4N, 135.1E, Kobe). in vicinity of the south west part of Sakhalin island. The trajectory of the earthquake July 12, 1993 contains the same patterns except the pattern near the Noto and contains additional pattern at the source of the earthquake May 26, 1983 (Akita). The trajectory of the earthquake October 4 1994 contains the same patterns also. We conclude that the surface wave of the great Earthquakes induced the secondary earthquakes at the area of the future earthquakes .

SOURCE PROCESS OF THE 1993 KUSHIRO-OKI EARTHQUAKE

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Hokkaido island, Japan, is characterized by intermediate and deep earthquakes with deep seismic activity extending to a depth of 600 km. The Kushiro-Oki earthquake occurred beneath eastern Hokkaido on January 15, 1993 at a depth of 107 km with a magnitude of Ms=7.8. Using teleseismic body waves recorded at 17 IRIS stations we determined the source mechanism and rupture pattern of the earthquake. Despite its large magnitude it was identified as a single event. The strike, dip and rake were found as 170.6, 23.2, -1.9, respectively, the seismic moment as $Mo=3.69x10^{27}$ dyn.cm and source duration of T=18 seconds. Source parameter estimation suggests that a fault length of 50 km was associated with the earthquake. The average dislocation was estimated as 10 m and the average stress drop as 21 MPa. This earthquake occurred in a previously asesismic region between the lower and upper plane of a double seismic zone. In general, intermediate-depth earthquakes have shown little to no aftershocks for identification of the fault plane and rupture area.Fortunately, the Kushiro-Oki earthquake resulted in approximately 300 aftershocks of M>2.0. The hypocenter of the aftershocks have distributed horizontally from the lower plane to the upper one. The azimuthal distribution of the observed waveforms generated by the earthquake show that the pulse widths at stations located to the west of the source region are narrower compare to the pulse width of stations located to the east. This observation combined with the horizontal trend of the aftershocks provide a strong evidence that the rupture occurred on a horizontal plane and propagated unilaterally in WSW direction.

MODELLING BODY WAVES AT INTERMEDIATE DISTANCES (17^o–30^o) WITH A GAUSSIAN BEAM SUMMATION METHOD.

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Due to the attenuation of body wave in the Earth, we can not study small ($M < 6$) earthquakes with classical teleseismic methods. To obtain a good signal-noise ratio, we have to use body waves recorded at distances between 17°(under is the shadow zone) and 30°. At these distances the propagation effects through the upper mantle (triplications) are taken into account by the Gaussian Beam method. To determine an average velocity model for Europe, we study the Mw = 6.2 earthquake occured on july 20, 1996 near the Dodecanese Islands in Western of Turkey in the Aegean sea. This earthquake can be modelled at two ranges of epicentral distances. For body waves between 30° and 90°, Nabelek's method starting from the CMT solution for the mecanism gives a source duration of 8 seconds and a depth of 5 km with a Moment of 2.02 10^{18} N·m. The focal mecanism inversion is not well constrained because all stations are located on one side of nodal planes. The study of seismograms at epicentral distances between 17° and 30° (Very broadband stations located in Northwestern Europe) by the Gaussian beam method using a column of the 3SMAC upper mantle velocity model gives the same source duration and Moment. Using this velocity model, we propose to study smaller earthquakes occurring in Greece and Turkey.

SCALING RELATION BETWEEN EARTHQUAKE SIZE AND DURATION OF FAULTING FOR MICROEARTHQUAKES AT MOUNT ETNA VOLCANO (SOUTHERN ITALY).

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In this study we used ca. 180 microearthquakes recorded at Mt. Etna volcano in order to investigate the relation between earthquake size (radiated energy) and duration of faulting (predominant period) from the waveform analysis of the P-wave velocity pulse. The magnitude of the earthquakes ranges from 1.8 to 3.5 and the seismic moment fells between 10E19 and 10E21 dyne-cm. Previous studies based on spectral analysis of microearthquakes at Mt. Etna (Patanh et al., 1997) show that the relation between the seismic moment (Mo) and the corner frequency (fo) of the P-wave is given by Mo proportional to the fourth power of fo. We found that the relation between the radiated energy of the P-wave is proportional to the fifth power of the period of the P-wave velocity seismogram. The above two relations seem consistent with each other and confirm that the cube law (Mo proportional to the third power of fo), generally accepted for large earthquakes, doesn't hold true for microearthquakes.

RUPTURE DYNAMICS IN 3D: WHY IS IT ALWAYS COMPLEX?

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In collaboration with K.B. Olsen and E. Fukuyama we have developed new numerical techniques for the modeling of rupture propagation along a flat fault embedded in a simple 3D elastic half-space. We have studied several friction laws having a characteristic cut-off distance that we call D_0. This characteristic length is essential in order to obtain stable numerical results. It represents the distance over which energy is dissipated near the rupture front as it propagates along the fault. We studied with these methods the propagation of rupture along a fault loaded by a heterogeneous stress field that is the superposition of a smooth distant tectonic stress and residual stresses from previous events. We find that rupture follows closely the initial stress distribution if friction is a simple constant function along the fault. For more complex distributions of fracture resistance, complex patterns of slip distributions can develop, slip following closely the history of rupture. We discuss the different parameters that control rupture and we show that, at least for isolated large events, rupture is complex at a range of scales and that slip distribution is controlled not only by the overall fault size but by internal length scales related to the stress and strength distribution. Finally, we discuss rupture propagation and slip distributions inverted from near field data in terms of rupture dynamics.

EFFECTS OF SOME PREVIOUS EARTHQUAKES ON THE LOMA PRIETA RUPTURE

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We consider five earthquakes (Lake Elsman 1 and 2, 1963, 1964 and 1967 shocks) which were the only events with $M_L \geq 5$ during the 25 years preceding the 1989 M_W=6.9 Loma Prieta (LP) earthquake. Using a dislocation program based on Okada equations, we examine the stress transfer by the last 5 events on the LP fault in 2 models (Wald, 1994 and Beroza, 1994). We show that these previous events have not brought the LP fault closer to failure but we observe a correlation between the LP earthquake slip and the normal stress distribution. Different interpretations of this phenomenon are given.

EARTHQUAKE RUPTURE PROCESS IN COMPLEX MEDIA USING GENETIC ALGORITHM BASED WAVEFORM INVERSION

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The increasing development of broadband stations enables us to analyse in more details waveforms on seismograms. Consequently, seismologists are able to achieve precise rupture process models using teleseismic broadband records. In complex areas, propagation effects interferes with the source effects so the rupture information can not be easily extracted from the recorded seismic waveforms. To insure a proper determination of the source parameters, it is fundamental to take into account the geological structure in the broadband waveform simulation.
Using complicated media description for the seismogram simulation, the forward problem becomes complex and its processing through an inversion procedure requires a non-linear inversion approach. We have developed a non-linear inversion procedure using genetic algorithm (GA). The depth, the fault parameters and the source time function are the inverted parameters chosen by GA. The waveform simulation is performed using a 2-D hybrid method (Perrot *et al.* 1994) that allows us to describe any kind of interface and velocity model. We successfully applied this method to a synthetic data set. The next stage is the application to a real event.

Perrot, J., Deschamps, A., Farra, V. and Virieux, J., 1994, *Phys. Earth*, 84, pp. 240-270.

FAULTING IN A VERTICALLY INHOMOGENEOUS MEDIUM - NEGATIVE STRESS DROP BARRIERS

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Upward rupture propagation in strike-slip mode is analysed in a medium with variable elastic constants and pore pressure. It is shown that the available stress drop in such a medium may turn from positive into negative values when a rupture enters into layers of low rigidity and/or small pore pressure. In particular, the available data of fluid pressure versus depth in sedimentary basins within the San Andreas fault system, California, indicate that variations of pore pressure alone may result in the negative stress drop of magnitude exceeding 10 MPa at depth of a few kilometers. It is also demonstrated that a region of negative stress drop has strongly suppressing effect on propagating rupture. It means that a new class of barriers, characterized by negative value of the stress drop, is proposed, of which sediments would represent the most distinctive group. The presented model provides then, among other things, an alternative explanation of the suppression of rupture in sediments (the 1966 Parkfield, the 1979 Imperial Valley, the 1995 Kobe earthquakes) to that based on the rate and state variable friction law.

SEISMIC SOURCE STUDIES OF EL SALVADOR EARTHQUAKES

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We carry out a seismic source analysis of 5 earthquakes ($M > 5.5$) which occurred in El Salvador from 1965 to 1997. Two of them are associated to the volcanic axis (events of 1965 and 1986). Analog recordings are used to estimate the focal mechanism of these events. Events of 1982, 1996, and 1997, located in the subduction zone, have been studied using broad-band teleseismic and strong motion data. Source parameters have been obtained combining P-wave first motion, body wave modeling and inversion, and spectral analysis. Estimated parameters from these different methods are similar. A method for modeling strong motion data has been developed. We applied it to the 1996 and 1997 events using data from a network of accelerometers recently installed in El Salvador. Results from the 1965 and 1986 earthquakes, show strike-slip mechanisms with horizontal pressure axis along the volcanic axis and depths less than 20 km. For subduction zone events, results show intermediate depths, 53 – 190 km, with horizontal extension in the NE-SW direction for the 1982 and 1996 events. A reverse-faulting mechanism for the recent earthquake of November 1997 was obtained, its azimuth is in good agreement with the Middle America Trench.

SEISMICITY AND SEISMOTECTONICS OF PERU

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Earthquakes of Peru are associated to the subduction process of Nazca plate, with focus at shallow (h<60km), intermediate (60≤h≤350 km) and deep (h>350 km) depth, but it exists also an important seismic activity at shallow depth located at the interior of Peru with origin in a cortical deformation associated to intraplate process parallel to the Cordillera. Vertical cross section of hypocenters shows the geometry of subduction with different slope at southern and a seismic gap at northern region. Seismic sources of 16 earthquakes occurred between 1990-1997 have been determined from modeling of body waves and spectral analysis. Results show reverse faulting motion with horizontal compression in NE-SW to E-W direction for shallow focus and horizontal extension in NE-SW direction at intermediate depth with predominant normal motion. For deep earthquakes a different stress regime have been obtained at Brazil and Bolivia border, that may indicate a different origin

APPARENT STRESS VARIATIONS: CONSTRAINS ON EARTHQUAKES GENERATION MODEL

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Apparent stresses in earthquake foci are examined using the Harvard CMT catalog and the regional data about Middle Asia earthquakes. The latter data base gives possibility also to compare the stress regime at rigid asperities and at the main (weak) part of rupture zones. It was shown that despite of a very high variability in stress characteristics of individual earthquakes, the robust estimates can be obtained using the order statistics. Typical (in most cases median) values are reasonably stable and display a regular character of change. Among other results, a few layers of higher and lower apparent stress values corresponding with the depth structure of the continental lithosphere and of the Benioff zones were detected. The results obtained are discussed and interpreted in terms of the model of earthquake generation in process of metamorphic transformation of matter closely interconnected with the fluid-rock interaction. The results hardly can be explained in terms of the model describing the earthquake generation by the increase in tectonic stress level.

SEISMIC MOMENT AND ENERGY RATIOS FOR EARTHQUAKES IN SOUTHERN CALIFORNIA

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The ratio between seismic moment and radiated energy can be indicative for the properties of earthquake rupture like dynamic stress drop. We determined seismic moments for many earthquakes in Southern California ranging from M=3.5 to M=7.3 using various methods. For smaller events, we used surface wave based moment tensor inversions, for the largest events, like the Northridge and Landers events we also inverted teleseismic body waves and inverted these for rupture history. These different methods give very similar results, as do comparions of our moments for the smaller events with moments derived by other workers and we are confident that these moments are well-constrained. Kanamori et al. (1992) found a well-defined relationship between radiated energy and local magnitude and for the smaller events we used their relationship to determine the energy. For the larger events, we also calculated the energy by integrating over the source-time functions and the finite rupture. For Northridge, our energy values are consistent with those derived from the local magnitude and for the Landers earthquake it is similar to energy estimates obtained by several other authors. The relationship between radiated energy and moment that we find is not linear, instead we find that energy scales with moment to the power 1.2. This is inconsistent with a simple static stress-drop model and we present simple rupture models that can explain this relationship.

SE24.01 The Umbria-Marche earthquake sequence of 1997: first results

Convener: Ihmlé, P.F.
Co-Convener: Amato, A.

MAIN SHOCKS AND AFTERSHOCKS OF THE 1997 UMBRIA-MARCHE (ITALY) EARTHQUAKE SEQUENCE

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A long sequence of earthquakes, six of which with magnitude between 5 and 6, struck Central Italy starting from September 26, 1997. The three largest shocks caused severe damages and loss of human lives in Umbria and Marche. The seismogenic structure consists of a NW-SE elongated fault zone extending for about 40 km. The focal mechanisms of the largest shocks reveal normal faulting with extension perpendicular to the trend of the Apennines, consistently with the Quaternary tectonic setting of the internal sector of the belt and with previous earthquakes in adjacent regions. We discuss the main shocks and aftershocks hypocentral locations, proposing that extension in this region of the Apennines is accomplished by normal faults dipping at low angle (30-40 degrees) to the southwest, and confined in the upper 10 km of the crust. These normal faults might have reactivated thrust planes of the Pliocene compressional tectonics. The aftershock distribution and the damage patterns also suggest that each of the three main shocks have ruptured distinct 5 to 15 km-long fault segments, adjacent and probably slightly offset between each other.

STRONG GROUND MOTIONS DURING THE 1997 UMBRIA-MARCHE EARTHQUAKE SEQUENCE

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We present the strong ground motion data set recorded during the recent seismic sequence that occurred in central Italy on September-October 1997. Ground motion time histories have been recorded from the permament stations of the ENEL strong motion network, by broad band sensors (Guralp CMG40 and CMG5) deployed by the University of Nice and by the Istituto Nazionale di Geofisica during a temporary survey of the epicentral zone and by the permanent and temporary stations deployed by the Servizio Sismico Nazionale. We present the sensor characteristics and the available frequency bandwidth of recorded digital data. We list values of peak ground acceleration and velocity, and we show ground shaking maps during the largest earthquakes of the seismic sequence.

REGIONAL SEISMOTECTONIC CONTEXT OF THE SEPTEMBER-OCTOBER 1997 COLFIORITO EARTHQUAKES (CENTRAL ITALY)

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The September-October 1997 Colfiorito earthquakes and their aftershocks are distributed within a 30 km long band extending NNW-SSE from Gualdo Tadino to Preci. This band is located in an intermediate position between two well known seismic areas: the Gubbio area, to the north, and the Norcia area, to the south. For these areas, earthquake and microearthquake stress inversion analysis indicates a tensional stress field with SW-NE trending minimum principal stress axis. The focal mechanisms of the Colfiorito events show prevailing NW-SE normal faulting, giving a further evidence for SW-NE active extension in the Umbria-Marche Apennines. As far as it concerns a possible seismogenetic model, the Gubbio and Norcia seismicity has been interpreted as related to the activity of west-dipping normal faults detaching on a major east-dipping low angle normal fault zone. An analogous model is here proposed for the Colfiorito area on the basis of surface and subsurface geological data, integrated with the distribution and kinematics of the September-October seismic events.

EVIDENCE FOR HIGH VERTICAL ACCELERATIONS DURING THE 1997 UMBRIA-MARCHE (CENTRAL ITALY) EARTHQUAKES

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We found extensive evidence that the vertical ground accelerations produced during the main shock of the earthquake sequence exceeded 1 g at several locations. One such set of evidence comes from the area north of the village of Annifo, a region where extensive surface ruptures, indicative of a normal fault mechanism, are present. We observed that most of the rocks and stones which are numerous in this region of smooth hills and scattered limestone outcrops had been freshly moved, overturned, fractured and broken throughout a zone extending over about a kilometer on either side of the surface ruptures. The freshness of the cuts and fractures and the consistancy of the observations for thousands of rocks and stones indicate that they were thrown upwards during the earthquake, with breakage occurring at the time of impact. We observed the same phenomenon in another area located about 5 km to the northwest of this zone. Although we did not observe surface ruptures there, this area lies along the strike direction of the surface ruptures present at the first site. These observations confirm that the surface ruptures in the hills north of Annifo are the surface breaks of the seismic fault. Other evidence that vertical accelerations exceeded 1 g at some locations comes from the heavily damaged village of Là Molina, located about 20 km northwest of Annifo. Observations and eyewitness accounts clearly indicate that several heavy free-standing objects were thrown up in the air during the earthquake. We present some numerical simulations of these ground accelerations.

EFFECTS OF LOCAL AMPLIFICATION AT TWO STRONG-MOTION STATIONS AS INFERRED FROM SMALL AFTERSHOCKS DURING THE UMBRIA-MARCHE SEISMIC SEQUENCE

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During the seismic sequence started since September 26, 1997 in the Umbria-Marche border, two close-distance stations (namelly Nocera Umbra and Colfiorito) belonging to the Italian accelerometric network managed by ENEL (the Italian electric power agency) recorded more than one hundred earthquakes. In order to separate the site from the source contribution in this important data set, a detailed investigation of the local seismic response has been performed at these two sites. This analysis includes a study of the geological conditions and measurements of weak motions using 1D and 2D small-aperture arrays. Significant amplifications emerge from the aftershocks recording confirming the predominant role played by nearsurface geology.

SE24.01

UMBRIA-MARCHE EARTHQUAKE SEQUENCE: THE CONTRIBUTION OF THE UMBRIA, MARCHE AND ABRUZZO LOCAL SEISMIC NETWORKS

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On the 26th of September 1997, when the Umbria-Marche seismic sequence started, three local seismic networks have been operating in the central Apennines. The networks include a total of eighteen digital seismic stations within a radius of two hundred kilometers from the epicentral area. Each station is equipped with the same kind of digital record system (MARS88) and 3-component, short-period sensors. The networks have recorded a homogeneous and unique data set which covers the whole seismic sequence (fore, main and aftershocks). This data set, enriched with the data recorded by 15 mobile stations deployed in the epicentral area from the 18th of October, is used to test and improve our knowledge on the crustal models to be used for the earthquake location procedures.

UMBRIA-MARCHE EARTHQUAKE SEQUENCE: THE GNDT-UNIGE/OGS-DINMA AND SSN SEISMIC NETWORK

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Starting with the 18th of October, 1997, a 11 stations seismic network was deployed in the southern part of the epicentral area of the Umbria-Marche sequence. The network was installed between the town of Sellano, severely damaged by the Ms=5.5 of October 14, and the town of Norcia and covered an area of approximately 30 × 30 km^2. Additional coverage was provided by 4 stations located in the northern part of sequence. Overall, we have found that the location of the stations in the Southern part—5 inner and 6 outer stations—allowed for optimal monitoring of the earthquake sequence.
The instrumentation consisted of 10 Lennartz Le-3D (5 s and 1 s) seismometers equipped with MarsLite recording on 230 MBytes optical disks and 5 Mark L-22 3-D (2 Hz) seismometers with RefTek 72A acquisition on 1.0 GBytes HD. The network operated for a total of 16 days and during this period it recorded more than two hundred earthquakes with magnitude larger than 2.5. In this poster, we fully illustrate the network and the type of seismic data that have been recorded.

UMBRIA-MARCHE EARTHQUAKE SEQUENCE: SEISMICITY AND VELOCITY STRUCTURE TO THE SOUTH OF THE TOWN OF SELLANO

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We have used the data collected by the 15 stations network installed by the GNDT-DISTER/OGS-DINMA and SSN working group to determine accurate earthquake locations in the Southern part of the epicentral area of the Umbria-Marche earthquake sequence. In order to obtain accurate earthquake locations, we have used P- and S-wave arrival times from a total of approximately 200 earthquakes from which we have obtained a best fitting 1-D velocity model for the target area. Our preliminary results indicate a model featuring velocities as high as 6.4 at 6 km depth. The average weighted root mean square of the residuals for this model is approximately 0.060 s. Overall, our results show that 1) the seismicity follows the NW-SE trend of the Apennines, 2) most of the earthquakes display normal faulting although we have also isolated some earthquakes having both reverse- and strike-slip mechanism and 3) the seismicity in the area features some distinct earthquake clusters located as far South as Norcia.

PRELIMINARY ANALYSIS OF THE SURFACE EFFECTS PRODUCED BY THE UMBRIAN-MARCHE SEISMIC SEQUENCE AND POSSIBLE SEISMOTECTONIC IMPLICATIONS

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A field survey was performed during the 1997 Umbrian-Marche seismic sequence, with the aim to investigate the co-seismic surface deformations. Several morpho-structural elements associated with the mainshocks (ML>5) were identified and analyzed. The geometry of the surface ruptures is generally consistent with the extensional mechanisms from CMT focal solution of the major shocks. At present, the deformation pattern does not appear to reflect primary faulting. In the most intensive ground deformation area, some of the fractures are associated to known, steeply south-dipping, normal faults, while others occur where no structure has been previously mapped. Ultimately, the surface observation was compared to the expected elevation changes, through the modelling of different source parameters. The interpretation of geological data versus seismological data allowed us to make some hypothesis about the seismotectonics of the area.

PRE-SEISMIC SLIP ON THE 26/IX/1997, UMBRIA-MARCHE EARTHQUAKE FAULT? UNEXPECTED CLUES FROM A COMPARISON OF SEISMOMETRIC AND LEVELING DATA

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On 26 September 1997, two moderate size earthquakes (Mw 5.7 and 6.0) ruptured two sections of an unusually shallow dipping normal fault beneath the Umbro-Marchigiano Apennines producing no unambiguous surface faulting. The proximity of Line 21 of the Italian first order leveling network to the source region allowed us to explore any vertical strains that the region may have experienced between the past two surveys (1992-1951), that is, at the end of the cycle of preparation of the two earthquakes. The observed elevation changes exhibit a long-wavelength trend, probably associated with bulk uplift of the Apennines, and a series of 5-15 km wavelength anomalies of unknown origin. We calculated the expected coseismic elevation changes using a seismological model fault inferred from short-period and teleseismic data. Quite surprisingly, some of the anomalies appear coherent in sign with the expected coseismic signal, particularly in the subsiding area where observations are more consistent, but much smaller in magnitude. Although this coherence is too blurred to be taken as due to motion exactly on the mainshock fault plane, it is hardly coincidental. The IGMI is planning the releveling of Line 21 and of other significant lines to constrain better the fault geometry, particularly its anomalous dip, and to substantiate the case for pre-seismic slip on the mainshock fault plane.

A SITE EFFECT STUDY DURING THE 1997 UMBRIA-MARCHE EARTHQUAKES - I: FIELD INVESTIGATIONS

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Strong site effects have been observed during the two Ms 5.5 and Ms 5.9 main shocks of the Colfiorito seismic crisis which began on September 26, 1997 in Umbria-Marche (Central Italy). The most obvious indication of these site effects are the dramatic differences in damage shown by constructions of the same nature in neighbouring villages. In order to study the ground amplifications in the fault area, we deployed an array of 12 seismic stations equipped with 3-component L22 seismometers and CMG5 accelerometers in the Verchiano valley south of Colfiorito. The profile spanned the bottom of the valley with a spacing of 100 m between two adjacent stations, up to the top of Mount San Salvatore, 420 m above the valley. This network worked in continuous mode for five days and recorded two magnitude 4 and more than ten magnitude 3 earthquakes. Seismic active experiments using a 24-channel acquisition system and 14 Hz vertical and horizontal geophones were conducted at the same time in the 500 m wide, 1500 m long Verchiano valley in order to determine the thickness and characteristics of the alluvial infilling. A preliminary interpretation of the data using refracted arrivals and converted PS reflections indicates that the alluvium thickness in the central part of the valley is about 65 m, with P and S wave velocities respectively equal to 1500 and 500 m/s.

A SITE EFFECT STUDY DURING THE 1997 UMBRIA-MARCHE (CENTRAL ITALY) EARTHQUAKES - II: PRELIMINARY RESULTS

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A linear array of 9 seismic stations (3D L22 and CMG5) was set up across the middle part of the sedimentary filled valley of Verchiano (10 km south from Colfiorito) during 1997/10/20-24 period. The Verchiano village and the Colle and Camino hamlets located inside of the valley were heavily damaged (intensity X MCS) since the 2 main shocks of 1997/09/26. During the experiment, the valley was mainly enlightened by the Colfiorito (10 km north) and the Sellano (6 km south) active seismic swarms. 2 reference stations were also defined: the first one was installed in the village of Curasci (2 km east from Verchiano) where no destruction occured, and the second one on the top of Mount San Salvatore between Curasci and Verchiano where a church was destroyed. *(i)* Compared to the valley side ground motion, and for most of the events recorded, the recordings in the central part of the valley (piano di Verchiano) show an amplification of the lower frequencies (factor $\approx$ 2-4 under 9 Hz) associated with a clear lengthening of the seismogram duration (factor $\approx$ 1.5-2). *(ii)* The small aperture of the array implies that the radiation pattern of the sources should not be invoked to explain the variability of the amplitude recorded on the valley side. Thus, the influence of the source hypocenter *vs* the valley geometry and the linearity of the ground motion amplitude *vs* the event magnitudes will be simulated and discussed in comparison to the Curasci reference site.

THE SEPTEMBER-OCTOBER 1997 UMBRIA-MARCHE (CENTRAL ITALY) EARTHQUAKE SEQUENCE IN THE SEISMICITY AND THE ACTIVE TECTONICS FRAMEWORK OF THE CENTRAL APENNINE

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On the 26th of September 1997 the Umbria-Marche region was struck by a seismic sequence which damaged an area of about 400 km2. The main epicentres, according to preliminary intrumental data and macroseismic evidence, are located in an area where the seismic activity is rather high, in terms of either magnitude and frequency, but not uniform. The 1997 sequence, infact, seams to fill a gap inside the Apennine seismic belt resulting from an elapsed time of at least 700 years since the 1279 earthquake.

In this paper the active tectonics of the Apennine sector affected by the sequence is described toghether with the analysis of the main characteristics of the seismicity. It has been carried out a comparison between the long-term seismicity and the known active faults of the area.

The relationship between the historical earthquakes and the active tectonics framework allows to address some fundamental problems, such as the difference in lenght of the faults northward and southward the L'Aquila fault sistem, the more fragmented structural framework of the Apennine sector north of Norcia and the possible "triggering" between adjacent faults, which are related to the seismic regime which characterises the central Apennine.

THE CENTRAL ITALY EARTHQUAKE OF SEPTEMBER-OCTOBER 1997: GEOLOGICAL EFFECTS AND SEISMOTECTONIC HYPOTHESES

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During September-October 1997, a seismic sequence with three main shocks (Ms 5.5, 5.9, on Sept. 26, and Ms 5.5 on Oct.14) have struck the Umbria-Marche region (Central Italy), between the villages of Nocera Umbra and Sellano. According to the historical seismic catalogue an earthquake of M<6.5 occurred in this area in 1279, followed by moderade energy events in 1791 A.D. and 1838 A.D. (M=5.2 and 5.8). Recent seismic events occurred in 1984, with Ms 5.2 Gubbio earthquake to the north, and in 1979, with Ms 5.9 Norcia earthquake immediately to the south. Although earthquake-induced sliding of debris have been observed and mapped in the epicentral area along the fault scarps of the primary active normal faults, no real surface faulting were associated with the main two first shocks of September 26. By contrast, the third shock of October 14 produced discontinuous NW-SE coseismic tectonic ruptures (between 60 m and 500 m long) along a total length of 5 km. The tectonic features of coseismic ruptures and active faults, are in good agreement to the CMT focal mechanism solutions that indicate normal faulting for the three main shocks. Our results provide additional information on surface tectonic ruptures caused by moderate-sized earthquake, yielding some constraints on the seismotectonic implications. The Colfiorito earthquake sequence, is a complex multi-shocks on three main fault-fragments of the Central Apennines.

GPS OBSERVATIONS OF CO-SEISMIC DISPLACEMENT OF THE UMBRIA-MARCHE SEISMIC SEQUENCE

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The recent earthquakes which struck the Central Apennines on September 26, 1997 (at 00:33 $M_w = 5.7$ and 09:40 $M_w = 6.0$) and on October 14 ($M_w = 5.7$) occurred in a region which includes a GPS network. The most recent survey of the area, made by the Italian Military Geographic Institute (IGM), spans the interval 1993-1995. After the earthquake, monuments from this network were occupied with GPS to measure co-seismic displacements. We observed a maximum horizontal displacement of about 10 centimeters and maximum subsidence of about 20 centimeters. By a trial and error approach we modelled the co-seismic displacement field to yield a source mechanism. The starting model was inferred from focal mechanisms, source time functions and aftershock distribution. The dislocation model resulting from this analysis shows a good agreement with the fault plane solution and provides a strong constrain on the minimum depth of faulting, that has to be in the first 3 km.

RUPTURE GEOMETRY AND STRUCTURAL CONTROL OF FAULT FRAGMENTS DURING THE COLFIORITO EARTHQUAKE SEQUENCE OF SEPT.-OCT. 1997

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Coseismic surface breaks have revealed a complex pattern of extensional tectonic structures and secondary features during the Colfiorito earthquake sequence (three mainshocks with Ms 5.5 and 5.9 the 10/26/97, and Ms 5.5 the 10/14/97). Surface ruptures visible along a total length of 5 km were associated with the third seismic event (focal depth at 6 ±0.5 km, ING communication). Surface ruptures show 4 cm of average vertical slip, with about 5 cm of opened cracks and a slip vector pointing out a normal slip with a slight left-lateral component along the Renaro-Mevale fault. In contrast, the coseismic rupture did not emerge at the surface during the two first shocks. The analysis of normal faulting mechanism at depth and surface geology, combined with seismic moments of mainshocks, shows three distinct NW-SE trending and SW dipping active faults, along a total length of ~20 km, and with a listric geometry at depth. We define the small-size fault ruptures as fault fragments that refer to the minimum fault-area required for producing a visible coseismic deformation at the ground surface. The coseismic rupture episodes occurred on the three fault fragments showing a right stepping en echelon geometry, and apparently controlled by transverse structures with basement outcrops. These transverse structures seem to have acted as a barrier to the rupture propagation. According to the late Quaternary deformation of the region, previous seismic events occurred repeatedly on fault fragments with similar endpoints rather than along a single major fault segment.

SOURCE PROPERTIES OF THE CENTRAL ITALY EARTHQUAKE SEQUENCE OF SEPTEMBER–OCTOBER 1997

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The larger earthquakes in the Central Italy seismic sequence of September–October 1997 are analyzed using long-period and broadband seismograms collected from the Global Seismographic Network, including several stations of the MEDNET seismograph network. For the three largest earthquakes, Centroid-Moment Tensors (CMT) are determined using primarily teleseismic body waveform and the standard Harvard CMT algorithm. The smaller events ($4.3 \leq M_W \leq 5.5$) are analyzed using a modified CMT algorithm, which relies on the inversion of intermediate period surface waves recorded at local and regional distances. Focal depth and rupture propagation are analyzed by inversion of teleseismic broadband body waves. The earthquakes are located at shallow depth (around 5 km) and are characterized by normal faulting mechanisms, with a nearly NE–SW tension axis, and the presumed fault plane dips at a shallow angle towards the SW. The rupture of the mainshock shows northward (and updip) directivity. Only one of the events considered has a different faulting geometry, indicating instead right-lateral strike-slip faulting on a plane oriented approximately E–W, or left-lateral faulting on a plane oriented N–S. The September 26 mainshock (09:26 UT) accounts for only approximately 50% of the total moment release in the sequence.

STATIC STRESS CHANGES AND FAULT INTERACTION DURING THE 1997 UMBRIA-MARCHE EARTHQUAKE SEQUENCE

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The central Apennines (Umbria-Marche) were struck during september-october 1997 by a seismic sequence which started with a foreshock on september 4 and consisted of six earthquakes whose magnitudes range between 5 and 6. The moment magnitude of the mainshock is 6.0. These earthquakes occurred within a seismogenic volume that is elongated in the Apenninic direction for roughly 40 km. Focal mechanisms resulting from CMT solutions indicate normal faulting on shallow-angle faults. We study the static stress changes caused by the shear dislocations along these fault planes. Because locations and focal mechanisms of the aftershocks from the dense temporary network are not yet available, we limit our investigations to the largest magnitude events. Our goal is to investigate if the mainshock induced stress changes can explain the occurrence of the large magnitude aftershocks. The rupture of shallow angle normal faults (dip angles range between 35° and 45° arises the question of the orientation of the regional tectonic stress and of probable fault reactivation.

GEOLOGICAL EFFECTS OF THE SEPTEMBER 26, 1997 EARTHQUAKES IN CENTRAL ITALY

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On September 26, 1997, two earthquakes, M_w=5.7 and M_w=6.0, occurred in the axial zone of the Umbria-Marche Apennines of Central Italy. Two other shocks of M_w=5.5 and M_w=5.7 occurred on October 3 and 14, respectively. The epicentres of the first three events are located in the Colfiorito basin, an intramontane tectonic basin infilled with Quaternary continental deposits; the last event occurred nearby the Colfiorito basin to the SE, near the village of Sellano. Right after the Sept. 26 main shocks, field inspection of the capable faults in the Colfiorito basin, already mapped by the Camerino group, revealed that the Colfiorito border fault, the Tolagna fault and the Costa fault had been locally reactivated. Typically we observed free-faces with height in the range of 2-8 centimetres at the base of late Pleistocene to Holocene carbonate bedrock slickensides for lengths of several hundreds of metres. End-to-end surface rupture length is 8 km, 1.8 km and 1 km for the Colfiorito, Tolagna and Costa fault, respectively. The local geòmorphic, stratigraphic and structural setting clearly shows that the observed ground displacements are related to fault slip rather than ground failure due to shacking. This surface faulting has a remarkable tectonic significance, because it occurs along the faults that are responsible for the recent tectonic evolution of the area.

Origin of the sound produced by the Colfiorito's Earthquakes

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The seismic sequence of Colfiorito, in the Central Apennines, of the September-October 1997 has been characterized by strong "rumbles" associated with the large part of the earthquakes. This strong sound was mainly heard by the popolation, living in the epicentral area. The acoustic waves have been recorded by infrasonic sensors in the same sites of the seismic stations. The analysis of the infrasonic and the seismic signal allowed to establish the physical nature of the phenomenon. The sound is not produced by the ground displacement at the source, as inferred for the infrasonic wave associated to big earthquakes, but it seems to be due to the coupling of the seismic waves with the atmosphere.

The 1997 Colfiorito Earthquake Sequence (Central Italy): Insights on the Mainshock Ruptures from Near Source Strong Motion Records

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A small size foreshock and the three mainshocks of the Colfiorito earhquake sequence which occurred on September,26 (00:33(GMT) ML 5.5, 09:40 ML 5.8) and on October,14 (15:23, ML 5.4) have been recorded by a set of permanent and portable 3C accelerometers owned by ENEA and SSN. In particular, unsaturated recordings of the four events are available at the SSA2 accelerographs located in Assisi (max PGA = 0.18 g), 20 km NW of the epicentral area, aimed to monitor the monastery (http://www.dstn.pcm.it/ssn/index.html). The mainshocks have been recorded by a minimum of 4 and a maximum of 10 accelerographs at distances between 20 km and 90 km of the epicentral area. Body wave arrival times and polarizations inferred from strong and short period data are used to constrain the location of the fracture origin point, the fault geometry and mechanism of the events. S-wave polarigrams and source time functions obtained by Empirical Green function deconvolution are analyzed in order to investigate the sub-event complexity and the kinematic behaviour of the faulting episodes. Based on these fault kinematic models, inferences on fault slip distribution are obtained by modeling the S acceleration waveforms.

SOURCE INVERSION AND MACROSEISMIC MODELLING FOR THE UMBRIAN-MARCHE MAIN EVENTS

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We studied the two main events of the Umbrian-Marche sequence of September 1997. The source parameters have been obtained by moment tensor inversion. Only two stations with three components have been used to get the results which are in good agreement with the CMT solutions. Several detailed structural models, coming from different studies, have been used in the analysis. The macroseismic models, corresponding to the inverted and to the CMT solutions, have been determined using the synthetic seismograms calculated by the modal summation technique; such models are compared to the observed macroseismic field in order to test the reliability of the proposed models.

SE25 High-resolution seismics: theory, methods and applications

Convener: Lykke-Andersen, H.
Co-Convener: Brancolini, G.

SHARP DECONVOLUTION WITH APPLICATION TO SUPPRESSION OF MULTIPLES

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A novel approach to deconvolution is suggested, which is illustrated with modified predictive deconvolution for elimination of multiples from marine data. A new objective function for the respective filter design jointly with a proper choice for predication distance and operator length gives a base for so called **sharp deconvolution**. The function assumes that the noise in the corresponding convolution model is colored, the well-known prewhitening is substituted with a "precoloring" induced by auto-correlations of seismic traces and an extra term is also included: *an Entropy of Image Contrast*. The latter is minimal when the "image" of the earth's reflectivity is the most contrast, *sharp*. To some extend the approach combines predictive and spiking deconvolutions without a shot-waveform estimation: it yields suppression of multiples jointly with reconstruction of desired reflectivity series. On its turn a rather accurate estimation of the reflectivity of a sea-floor and an upper part of the underlying subsurface allows us to eliminate not only water-layer reverberations but intra-bed and pegleg multiples. The effectiveness of reflectivity reconstruction by sharp deconvolution is dependent on the validity of assumptions in the method, which provides for an unbiased estimate of the reflectivity when the latter can be represented with the *minimal number* of inherent parameters.
The method is demonstrated with processing of synthetic and real marine data.

HIGH RESOLUTION SEISMIC STRATIGRAPHY OF PALMER DEEP: A FAULT BOUNDED LATE QUATERNARY SEDIMENT TRAP ON INNER CONTINENTAL SHELF, ANTARCTIC PENINSULA PACIFIC MARGIN

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The Palmer Deep is a small enclosed bathymetric depression up to 1400 m deep containing a thick (about 270 m) sediment fill that includes at its top a ultra-high resolution Holocene record of a proximal glacial depositional environment. It is suggested that this seafloor depression acted as subglacial "lake" beneath the ice sheet at times of glacial maximum.
A comparative high resolution single channel seismic stratigraphic study has been conducted using a deep tow boomer (HUNTEC), a GI gun (2.5 l) and a small volume conventional air gun (0.25 l). An attempt to survey the area with a 0.16 l water gun has proven unsatisfactory because of excessive water depth and low signal to noise ratio induced by surface waves. The results of the surveys have allowed us to obtain a complete high resolution seismic stratigrpahic scheme of the sediment fill and the correlation of shallow reflectors detected with deep- and surface-towed sources.
The three surveys have permitted the location of sites for ODP drilling (Leg 178, February-April 1998) in the narrow seafloor depression. The ground truthing of the seismic stratigraphy, obtained by drilling, will be presented as preliminary result.

OPTIMAL GRID CHOICE FOR LINEAR TOMOGRAPHY PROBLEMS

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The problem of the optimal choice of the source-receivers layout for tomography imaging as well as the optimal grid choice are discussed. The approach based upon analysis of the resolution matrix for a linear, $l2$ - norm based tomography problem is studied.

NEAR SURFACE SEISMIC EXPERIMENTS ON AN ANTICLINAL FLANK. FIELD AND NUMERICAL DATA.

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Near surface seismic imaging gives very good results when the structure of the geologic target presents a simple geometry. But we wanted to test this know-how, in a complex tectonic structure. We choosed an anticlinal flank as a test site. The layers outcrop and dip strongly (30 degrees). The variations of lithology (limestones, marls...) induce very important changes in the thickness of the weathered zone and the elastic behaviour of the ground.
The field data recorded on this site present great changes in terms of spectral content and signal to noise ratio, related to the lithology. Reflected signals appear rarely, hidden by a strong ground-roll. Many diffractions are observable. Numerical experiments were carried on. The models used get only two layers. The less competent one (marls) is recovered by a slow thin layer (a weathered zone), the more competent one (limestones) outcrops. Simulations made by solving the wave equation give data closed to field data, and show that we must consider P, S, rayleigh waves, and conversions to explain the observed phenomenon. Experiments made by ray tracing allow us to get informations about the reflected signals, and the origin of diffractions.
Those results should allow us to recognize the informations the field shots gathers may get.

DEVELOPEMENT AND OPTIMIZATION OF NEW METHODS TO DECONVOLVE DATA OF INTRUMENTAL DEVICES: γ VERSION

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We have developped an experiment in acoustic curve to studie wave propagation. The frequency response of the different devices of the experiment corrupt the recorded data. The aim of this work consists of data deconvolution of the global instrumental response of all equipments and sensors to correct recorded data. We propose two method to build the experimental filter necessary to realize this deconvolution. The first method uses the simple reconstruction formula of the wavelet transform and the secund, more general,is founded on building a filter basis. These two methods based on a reconstruction formula avoid the classical problem due to deconvolution. We test these two methods on synthetic examples firstly and on real data recorded in acoustic curve.

ANALYZING AND FILTERING OF COMPLEX WAVETRAINS IN BOREHOLE WITH THE CONTINUOUS WAVELET TRANSFORM: γ VERSION

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We propose a method to analyse and filtering complex wavetrains in borehole with the continuous wavelet transform. This method is based on two steps: Firstly we use the wavelet transform to analyse complex wavetrain recorded in borehole. The time frequency representation allow us to detect precisely the wavetrains corresponding to the interfaces waves that corrupt recorded data in borehole (Stoneley wave etc...) After this analysis we select the part of the time frequency plan corresponding to the interface waves that we want to filter. We use the reconstruction formula of the wavelet transform to rebuild the wavetrains associated with this part of the time frequency plan. At this moment we have the exact signature of the interface waves, so, we can easily filter them of the recorded data. To test this method we realized an acoustic experiment, in a miniature concrete borehole in an acoustic curve. We observe the same problems that in real full waveform data acquisition. We show the result of this filtering method on these real data.

DEVELOPEMENT AND OPTIMIZATION OF A METHOD OF SEISMIC ENDOSCOPY IN BOREHOLE IMAGING: γ VERSION

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The aim of this work concerns the development of an endoscopic borehole seismic method for imaging a volume for some meters around the borehole.The concept of this method is based on directionally sensitive data recorded in the borehole, so as to detect the precise azimuthal location of an object relative to the borehole. Due to rotation tool in the borehole, it is necessary to correct the recorded data.To do this, we apply a special azimuthal correction based on the same principle as Normal Move Out. We have called this method Azimuthal Move Out (AMO). We show the results of this correction on data recorded in the acoustic tank. The principal problem, if we want to obtain an image around the borehole, is the range of different waves (Stoneley, Pseudo Rayleigh,...) which mask the reflections that come from borehole far field. We propose a new method based on a dynamical correction based on the decentring tool in borehole to filter this waves. We have called this new correction SMO, for Stoneley Move Out. We show some results of this filtering method on data acquired in a miniature concrete model borehole in an acoustic tank. At the end we propose an algorithm to realize a three-dimesional imaging around the borehole.

GENERATING OF DIRECTIONNAL BESSEL BEAMS FROM SOURCES IN A HYPERPLAN: APPLICATION IN GEOSISMIC EXPLORATION. SUBMISSION: γ VERSION

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The analysis of geological structure is generally done with the help of point sources generating spherical waves. These highly symmetric waveforms do not have any privileged direction a priori. We propose a method to generate directionnal non diffracting beams in a arbitrary observation point of a homogeneous half space from sources located at a hyperplane. We show that there is a critical angle below which thus waves cannot be generated any more. In case the angle is subcritical, we prove a sampling theorem allowing the generation of Bessel beams from infinitely many isolated point-sources. We discuss how this analysis allows a directional recomposition of seismic traces.

HIGH RESOLUTION SEISMIC SURVEYING IN THE EASTERN DANISH NORTH SEA

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During the years 1994-97, approximately 6000 km of high resolution seismic profiles were acquired in the eastern part of the Danish North Sea sector employing the Danish research vessel F/S DANA (94-96) and the survey vessel Gribben (97). Post-stack bandwith of the data is 40-180 Hz providing a vertical resolution in the order of 5-10 m and penetration to 1-2 s TWT (1-2 km). Basic equipment consists of a cluster of 4 sleeve guns with a total volume of 70 cu. inch. and a 144 m, 24 channel streamer (94-96) or a 600 m, 96 channel streamer (97). Shot-interval was 12.5 m resulting in 6 or 24 fold coverage. Data were processed using ProMAX (6.0) on a SUN Sparc 20 workstation. Main problems encountered were: lack of penetration in rough weather and short period sea bed multiples. Lack of penetration was irretrievable but multiples could be suppressed during the processing. Predictive deconvolution was applied with varying success whereas radon-filtering proved very successfull in removing the shallowest and most problematic multiples. Among the most conspicuous geological features seen on the seismic data are: Channels and mounds in the top of the Upper Cretaceous to Danian Limestone, Oligocene and Miocene southward prograding deltas, thrusted (?) sediment packages detaching near the mid-Miocene unconformity and a large system of more than 300 m deep and a few km wide buried Quaternary valleys. Furthermore amplitude anomalies indicate the presence of considerable amounts of gas in some parts of the Cenozoic succession.

EXPERIENCES FROM SHALLOW REFLECTION SEISMICS OVER GRANITIC ROCKS IN SWEDEN

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Most reflection seismic experiments in Sweden have been on a crustal scale, but a number of high resolution surveys with targets in the upper kilometer of crust have also been carried out. In these shallower surveys we have often had access to boreholes for control of our interpretations. Three of the surveys reviewed here were carried out with station spacings of 5 or 10 m (Dala Sandstone, Finnsjon, Avro) while the other two surveys were of a more regional character (Siljan Ring, Varmland). Results from these latter two are shown since they provide good images on conditions at depths of less than 2 km. In granitic rock type environments in Sweden two predominant sources to seismic reflections are found, dolerite intrusions and fracture zones. Dolerites were found directly in the deep wells in the Siljan impact structure and were inferred to be present from the seismic data in the Dala Sandstone area. Similar sub-horizontal reflections have also been found below the Bothnian Sea. The dolerites represent high impedance layers in the host granitic rock and are sub-horizontal to gentle dipping. The fracture zones contain free water and, thus, represent low impedance layers in the granitic host rocks. They can be sub-horizontal to steeply dipping and are generally less laterally continuous than the dolerites. Polarity analyses of the seismic data is a method to differentiate between dolerites and fracture zones in granitic rocks.

SOME IMPLICATIONS OF THE FIRST-ORDER ELASTIC WAVE RAY THEORY FOR INHOMOGENEOUS ISOTROPIC MEDIA

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We are concerned with two very different effects of inhomogeneity of the media described by the first-order ray theory. **I. Weak Boundary** where the velocities and the density are continuous but their derivatives suffer jumps, does not influence on the description of seismic waves when only the zero-order term of ray series is taken into account. Important is the transmission zone, modelled by a layer with constant velocity gradient, framed with two weak boundaries. We consider all the waves reflected, transmitted, converted at each boundary, which are forming the resulting wave reflected from the layer. For all the wave species rather simple expressions are found. **II.Dilatation of the S wave** is described in smoothly inhomogeneous isotropic medium via employment of both the zero- and first-order terms of the ray theory. It is observed that the dilatation is necessarily dependent upon the inhomogeneity of the medium, vanishing in the instance the medium is taken homogeneous. This research was done in response to the progress made in the field of extensometry and we are motivated to investigate the effects of inhomogeneities on the dilatation of S waves, which can nowdays be measured directly. This may prove imporatnt in wave discrimination.

MULTI-SCALE SEISMIC INVESTIGATIONS, DANISH NORTH SEA - ILLUSTRATED BY DETAILED MAPPING OF THE RUBY SALT DIAPIR

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A 5-year joint mapping project commenced last year with 800 km of multi-scale seismic data being acquired in the eastern Danish North Sea. The objective of these investigations is to cover the entire Danish North Sea Sector within the 5-year period, enabling very detailed mapping of the Cenozoic development of the area. The multi-scale investigations simultaneously employ a 96-channel sleeve-gun system (40-250 Hz), boomer (450-2000 Hz) and side scan sonar (500 kHz), providing very high resolution (better than 1 m in the shallow subsurface) and moderate penetration (1500-2000 ms). Integrating the different datasets has strong implications for the interpretation of surface, near-surface and deep expressions of various geological processes. These include: salt tectonics, sediment deformations, glacial phenomena and post-glacial development of the area. This is illustrated by an integrated study of the "Ruby" salt structure situated in the salt dome province in the NE part of the Danish North Sea. Multi-channel seismics image deeper parts of the structure from the base of the Upper Cretaceous-Danian Chalk Group to the base of the Quaternary, whereas the boomer data image the Tertiary-Quaternary boundary and the structure of the Quaternary deposits which thin dramatically across the structure. Side scan sonar and boomer data both reveal a slight updoming of the seabed across the structure. This feature and the occurrence of an onlapping Postglacial succession

Screw seismics

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Previously, Ødegaard A/S and Texaco Ltd. (Kevin Davies, Gary Hampson, and John Ødegaard) have demonstrated that it is possible to use screw noise as a marine seismic source. The generation of bubbles near the propeller and their collapse (cavitations), are of main importance for the noise generation. Further investigations have been carried in the North Sea by use of Dana, a Danish research vessel. It has been demonstrated that reflected energy can be achieved to a depth of about 1000 ms two-way traveltime. Data are processed very much like vibroseis data. The streamer signals are correlated with the screw noise, which is detected by hydrophones mounted in the hull right above the propeller. Intensive use of FK-filtering is applied in order to suppress energy coming directly from the source. Systematic recordings of the noise spectra have demonstrated that low pitch (propeller angle) and high propeller speed give maximum cavitation and thereby maximum source energy. The source spectra are relatively flat for frequencies between 40 Hz and 200 Hz, which is also the frequency range of interest for shallow seismic investigations. The peak frequency is present at about 70 Hz. The main frequency range for the screw noise can to a certain extent be controlled the pitch and propeller speed.

SE26 3-D seismic modelling and high performance computing

Convener: Seron, F.J.
Co-Conveners: Maggio, F.; Sabadell, F.J.

APPLICATION OF HIGH-RESOLUTION SEISMICS ON RIVERS FOR NEOTECTONIC AND RIVER DYNAMIC STUDIES

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Several high-resolution seismic surveys have been carried out on the two major rivers of the Pannonian basin during the last two years. These surveys included both single-channel, ultra-high resolution boomer and multi-channel, high-resolution air-gun surveys. The two rivers represented very different geological scenarios. River Tisza is a meandering river flowing above the subsiding part of the basin. Below the present day river course ancient river beds have been imaged. The collected profiles form a superb dataset for stratigraphic and river dynamic studies and several indications of paleoclimatic variations have been observed. River Danube on the other hand flows above an uplifting part of the basin and the very thin recent river deposits overlay a strongly deformed Oligocene strata. The very low water level late 1997 exposed the rocks in the riverbed, thus geological mapping and sampling of the previously surveyed area was possible. Densities and acoustic velocities have been measured on the rock samples and modelling based on the measured physical properties has been carried out. The results have been compared with the single- and multi-channel data. Faulting could be observed and compared at three different scales, outcrop, ultra-high resolution (0.1 m) and high-resolution (1-5 m) scales.

ULTRA-HIGH RESOLUTION SEISMICS ON THE LAKE BALATON, HUNGARY: PROCESSING AND INTERPRETATION

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In September, 1997 a single-channel ultra-high resolution seismic survey was carried out on the lake Balaton, Hungary. A boomer source and a line-in-cone hydrophone group built on the same catamaran body was tested for the first time on the lake with exceptionally good results. The average water depth of the lake Balaton is 3 m and 2-3 m thick Holocene mud covers the underlying Pleistocene strata. This thin mud layer represents a gradual transition between the water and the older Pleistocene sandstone strata, therefore only week multiples were generated on both the water-mud and the mud-sandstone interface. This fortunate geological situation and the very low noise level achieved during the survey ensured 50 m penetration and 0.1 m post-processed resolution. Very fine layering of the Holocene mud was revealed indicating climatic variations during the last few thousand years. Strong angular unconformity has been observed between the Holocene and the Pleistocene strata. The strongly tilted and deformed older lacustrine sediments show several remarkable tectonic and stratigraphic features. All this has been imaged at outcrope scale on the seismic records. The paper presents the highlights of more than 200 km lines collected. Acqusition and processing details will be discussed together with tectonic and stratigraphic interpretation.

3D SEISMIC MODELLING OF COMPLEX MEDIA BY THE MORTAR METHOD

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The adoption of spectral elements for the computational treatment of wave propagation problems brings a significant reduction in the number of grid-points to be used in order to avoid numerical dispersion. On the other hand, the finite element method allows a greater flexibility in dealing with problems posed on higly irregular domains and/or involving complex constitutive laws. We present an effective hybrid finite element - spectral element method for the approximation of elastic wave equations in 3D domains which allows to exploit the good features of both the methods mentioned above. Our coupling algorithm is based on the "relaxation" of the continuity condition on the interface between regions where the two different methods are used, namely the mortar projection method. The resulting algorithm enjoys *optimal* accuracy, We illustrate its practical implementation along with validations on 2D and 3D significant test cases.

SE26

TREATMENT OF CORNER AND BOUNDARY EFFECTS IN ELASTODYNAMIC NUMERICAL SIMULATION

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Numerical simulation of elastic waves propagation by resolution of the wave equation requires to introduce an artificial boundary. It must be treated in such a way that we simulate a semi-infinite medium. Classical absorbing boundary conditions are quite unefficient for grazing and Rayleigh waves. We propose 2 methods to attenuate signal due to boundary and corner effects. Both consist in enlarging the geological velocity model and in perturbating it in this area. We called the first one "scattering bands". The velocity model is perturbed by a gaussian function on small discs randomly distributed in the bands. The reflections on the boundaries are replaced by scattering noise which is not correlated and then disappear on the stacked data. The second method is specially designed to attenuate corner effects. It is based on the concept of "anechoic chamber" in acoustic methods. We add tips near the surface corners and impose a large velocity contrast with the first layer. Their geometrical parameters are fixed by the wavelength of the seismic signal. These tips act like waveguides which trap the undesirable signal. They are particularly efficient to make reflected and diffracted Rayleigh waves disappear at the corners. We propose another geometry of the tips for borehole and 3D seismic simulation.

PSEUDOSPECTRAL METHODS FOR GLOBAL SEISMOLOGY

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Today's high-quality data warrant models with 3-D heterogeneity and anisotropy, requiring fast and accurate forward solution methods. Many such methods have been developed, each of them with its problems: coupled-mode theory, direct solution methods, ray theory and finite differences. Pseudospectral methods, relatively new to the numerical repertoire, promise a practical and general means of solving the wave equation. Like finite differences, they work in the time domain; however, the wavefield is represented as a Fourier sum, producing highly accurate spatial derivatives. This greatly reduces the number of required grid points, making pseudospectral schemes practical on high-end workstations. Although pseudospectral methods have previously proven effective in local seismology, they have not yet been applied to problems in global seismology. Difficulties special to the global problem include a significantly non-Cartesian geometry, widely varying model parameters and sharp contrast of parameters at the core-mantle boundary. We are developing pseudospectral methods for global seismology, focusing on the difficulties inherent to the global problem, especially the boundary conditions. We have implemented a 3-D Fourier pseudospectral code in spherical geometry and have matched its output to that of normal modes. Future use of the pseudospectral method in global seismology will incorporate the Earth's ellipticity, 3-D mantle heterogeneity, laterally variable crustal structure and surface topography.

3-D Numerical Seismic Modeling in Global Seismology

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To understand the full wave signature of geodynamical features such as subduction zones, hot spots, lowermost mantle structure (D"), etc. numerical solutions to the wave equation in spherical geometry are required. Several algorithms are presented for different domains of application (e.g. rotationally symmetric media, spherical sections, sphere) using a variety of numerical techniques (finite differences, pseudo-spectral method, natural-neighbour techniques on irregular grids). These algorithms are implemented on parallel (symmetric) hardware using High Performance Fortran. The accuracy of these different methods, their capabilities and limitations will be discussed. Examples for wave propagation through models of subducting lithosphere obtainded by numerical modelling of mantle convection demonstrates the necessity for complete wavefield calculations in global seismology.

3D SEISMIC MODELLING OF A TOPOGRAPHY USING A TIME-DOMAIN BOUNDARY ELEMENT METHOD

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We present a boundary element method to compute the diffraction of seismic waves by a 3D topography overlying a homogeneous elastic half-space. This method is based on an integral representation of the displacement and traction fields, derived from Somigliana's identity. The discretization scheme approximates the interface with a collection of disks that allows to regularize the singularities of the kernels to integrate. Calculations are performed in the time domain with a time-step small enough to ensure that the boundary conditions are expressed in an explicit manner and that no linear system has to be solved. The performances of this algorithm are satisfactory: the computation does require less than 100 MB of core memory for a 75x75 gridsize, and it takes few hours on a workstation.
We show some results for the diffraction of incident plane waves and point sources by 3D topographies (hemispherical cavity, gaussian hill, ...). Although a rough surface discretization is used, 3 to 4 points per minimum wavelength are enough for our results to compare well with other methods (e.g. finite differences, pseudo-spectral methods), even for sharp boundaries. Our next step will be to treat more complicated models with multiple layers and possibly non-homogeneous media.

COMPUTER MODELLING OF SEISMIC EVENTS IN THE CASE OF DEGENERATION OF THE REGION

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3-D elastodynamic problem for a half-space is considered in the case that the region under interest is thin and its large linear size is comparable with the wavelength of the dynamic process studied. The degeneration of the region into a line (a mountain ridge, a valley, a river, a tunnel, a strip foundation) or into a surface (a coal seam) makes it hard to implement numerical solution. On the basis of asymptotic analysis fulfilled the original dynamic problem is reduced to the superposition of two problems of decreased dimension. The first one is governed by an integral equation over a mid-line (a median suface) and describes 3D dynamic effects of the process. The second one is 2D (1D) quasi-static problem and describes the deformation in the transversal direction. The unknown displacement is calculated numerically. The results present a good test to fully numerical solutions.

SEISMIC RESPONSE OF 3D TOPOGRAPHICAL IRREGULARITIES UNDER INCOMING ELASTIC WAVES FROM POINT SOURCES

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We study some effects that produce 3D topographical irregularities under incoming elastic waves from point sources using the indirect boundary element method. This technique is based on the representation of elastic waves in terms of single-layer boundary sources. In this way reflected and diffracted waves are constructed at the boundaries from where they are radiated by means of boundary sources. The field emmited from the point source is computed with the moment tensor for a shear dislocation and analytical expressions of the elastodynamic 3D Green's functions. In this way we can construct a double couple with variable orientation. We compare the technique with that of Bouchon, who used the discrete wave number method for a shear dislocation in a halfspace with a triangular source function. We subsequently apply our method to simulate the seismic response of mountains and cavities of ellipsoidal geometry. The source function that we have considered is a triangular pulse and we show results corresponding to synthectic seismograms of velocity registered over the surface of the irregularity and that of the halfspace. The seismic motion is presented also by means of different snapshots showing the evolution of the wavefields that are present in the problem.

SIMULATED ANNEALING IN 3-D SEISMIC MODELLING: ELASTIC STRUCTURE OF THE MEDITERRANEAN BASIN FROM RAYLEIGH WAVE VELOCITY DISPERSION DATA

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The simulated annealing algorithm constitutes an useful tool when dealing with inverse problems in Seismology, where partial derivatives involved in other classical inversion procedures are often difficult to compute analitically. Provided that the annealing algorithm is based on a repeated solution of the forward problem for randomly generated earth models, making use of a set of thermodynamic analogies, the computation of partial derivatives becomes unnecessary. Mathematical properties of the aperiodic Markov chain representing the annealing process removes the usual dependende of the solution on the sometimes arbitrary starting model. Moreover, the specific characteristics of the algorithm avoid the inversion process to be trapped in secondary minima of the likelyhood function, thus assuring that the obtained solution would be the best possible. An application of the simulated annealing algorithm to 3-D modelling of the crust and upper mantle elastic structure of the Mediterranean basin from Rayleigh wave group velocity dispersion data is presented.

HYBRID MODELLING OF GROUND MOTIONS AT A SEDIMENTARY BASIN

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Hybrid methods enable to engage the far source and the long path effects into the computations of the ground motions at a site. The contemporary hybrid methods involve modal summation coupled with finite differences (FD), and discrete wavenumbers (DW) coupled with FD. To expand the ability to treat not only 1D but also 2D and 3D crustal structures, a new hybrid method based on rays combined with FD has been recently introduced, too. However, the limitations of the ray method bring in question the accuracy in terms of completeness of the solution both in time and frequency domain. Hereby we investigate the hybrid methods in extreme situations as, for example, fast spatial variations of the material parameters, models involving non-planar surface topographies, high v_p/v_s velocity ratios, and models with stochastic velocity perturbations. Building new 3D codes requires robust FD algorithms well tested in 2D models of realistic sites. We compare the ray-FD and DW-FD methods on examples of a sedimentary valley excited by nearby shallow earthquakes. The model involves the spatially varying Q, proportional to frequency, and a source offset from the FD model plane. The methods have been prepared for applications within the international EUROSEISTEST site at Volvi Lake, Northern Greece.

LARGE SCALE 3D MODELING OF SEISMIC WAVE PROPAGATION ON A MASSIVELY PARALLEL MACHINE

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Studying seismic wave propagation on about a hundred wavelengths, in a 3D model, with a precision of a tenth of a wavelength, leads to models of 1000×1000×1000 grid points with a method such as finite differences or finite elements which is necessary to model any kind of wave (P, S, Rayleigh, Stoneley, Love, ...) for realistic media. To achieve this aim, the author uses a precise high order finite differences method on a staggered grid (8 points in space, 4^{th} order in time) to have at least 3 points per shortest wavelength. Absorbing boundary conditions are implemented following the Higdon's method. Free surface boundary conditions are carefully applied with exponentially decreasing grid mesh in the vertical direction. The numerical scheme has been implemented on a Cray-T3E massively parallel machine, using the Message Passing Interface libraries and SHMEM-Cray intrinsics and is fully scalable. 400×400×400 models can be run now on a 168 processors machine at a sustained average speed of 30 MegaFlops/s with a low level of optimization. This allows now the study of physical phenomena such as site effects amplification in sedimentary basins.

A MULTIBLOCK ALGORITHM FOR PARALLEL WAVE PROPAGATION

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Wave propagation problems arise in many areas of applications. The use of parallel computers makes feasible to simulate elastic waves throughout large heterogeneous structures by means of recent advances in domain decomposition methods. In this work, we introduce a simple parallel algorithm for the propagation of elastic waves in complex heterogeneous media after a finite element discretization. This parallel method performs more efficiently than classic domain decomposition techniques based on substructuration. Some numerical examples are shown, as well as studies on the efficiency and performance of the algorithm in relation to classic domain decomposition techniques based on substructuration.

3-D SPECTRAL ELEMENT-BY-ELEMENT WAVE MODELLING ON CRAY T3E

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Highly efficient algorithms and massively parallel computers are needed for acoustic full wave modelling in large scale 3-D realistic complex media.
In this work a spectral element method in conjunction with a new iterative solution technique is presented. The very high spatial accuracy of the algorithm allows for increased computational efficiency when compared to standard finite element method. In addition, the use of an iterative solver, based on a local element-by-element formulation and a matrix-vector product which is factored and converted to a faster matrix-matrix product, allows for a significant reduction both in storage requirements and in the computational complexity. The resulting algorithm can easily be implemented on high-performance vector and/or parallel processors. The numerical scheme has been tested on a Cray T3E supercomputer. Our experimental results show that efficiency is very high and that good load balancing can be obtained at run time, because relevant blocks of computations are performed at the element level and are totally independent.

MODELLING TECHNIQUES FOR VOLUMETRIC RECONSTRUCTION OF EARTH STRUCTURES

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The obtaining of seismic velocity structures from surface wave implies to deal with pathwise integrals of the velocity field along trajectories. A normal procedure consists of regionalization of dispersion curves by means of a tomographic technique not based on discrete blocks. In this work we show how the use of interpolation techniques can be used for tomography purposes as well, since they provide straightforward and non expensive algorithms to reconstruct data. We propose different methodologies and perform an overall comparison among them, enlarging their properties and feasibility to carry out tomographic studies with surface waves. We show that the regionalization of volumetric structures is possible without involving any inversion procedure. Special emphasis on the accuracy of the methods is provided by studying the results obtained after several synthetic tests from different heterogeneous models. Two applications to real data are attempted as well. In our volumetric representations, the velocity fields are displayed as colour patterns, easing the interpretation of the data and allowing a better visualization of the solution.

A PRACTICAL REGULARIZATION IN KRYLOV SPACE FOR SEISMIC TOMOGRAPHY

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Regularization is usually necessary to solving seismic tomographic inversion problems. Because in general the equation system of seismic tomography is very large, making a suitable choice of the regularization parameter may be very computationally demanding and therefore practically difficult. We present an algorithm to convert this problem to a more amenable form. We first transfer the system of equations into a Krylov sub-space by using Lanczos bidiagonalization. In the transformed sub-space, the system of equations is then changed into the form of a standard damped least squares normal equation. The solution to this normal equation can be written as a explicit function of the regularization parameter, which makes the choice of the regularization computationally convenient. Two criteria for the choice of the regularization parameter are investigated with numerical simulations. If the dimensions of the transformed space are much less than that of the original space, the algorithm can be very computationally efficient, which is practically useful in large seismic tomography problems.

AFTERSHOCK SERIES OF EVENT FEBRUARY 18, 1996: AN INTERPRETATION IN TERMS OF SELF-ORGANIZED CRITICALITY

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An aftershock interevent time series, initiated on February 18, 1996, in the eastern Pyrenees was analyzed. The original time series does not fit Omori's law, probably because of sudden changes in the rate of occurrence, interpreted as an increase in the production rate. When the recorded interevent time series is classified in terms of leading aftershocks (those that satisfy a relaxation process) and cascades (those occurred at a nearly constant rate), the new time series of the leading aftershocks fits Omori's law quite well, with $p = 0.94$. Interpreted in terms of Dietrich's model, the series of leading aftershocks correctly predicts a return time for the main shock of the order of 50 years. To interpret the series of cascades, a minimalist, self-organized critical model was used. Although it is very simple, the model correctly reproduces the two-level structure in the observed time series, that is, the sequence of leading aftershocks and a cascade sequence emerging from each aftershock. This model may be given physical justification in terms of the *Cochard and Madariaga* [1996] nucleation model.

SE27 Mechanics of tectonic and volcanic earthquakes (co-sponsored by NP)

Convener: Sileny, J.
Co-Convener: Panza, G.F.

AUTOMIZED MOMENT TENSOR INVERSION OF FLUID-INDUCED MICRO-SEISMICITY IN SALT

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Amplitude spectra of body-wave phases are used to estimate moment tensors of swarm-events in an automized procedure. For this, single and multiple event methods have been extended to amplitude spectra data, and to one component sensors with known orientation. The resulting nonlinear inversion problem is, after a Taylor series expansion, iteratively solved beginning with an initial source model. To avoid convergence to a local minimum we use a grid search over initial fault orientations on the focal spheres and choose, after a number of fixed iterations, the solution having the least residuals between observed and predicted amplitude spectra. To further stabilize the inversion we optionally use a general dislocation source constraint. The methods are tested on synthetic waveform data and on fluid-induced micro-cracks in salt. There, about 100 events span a volume of $\approx 1m^3$ surroundig a macro tension-crack with a radius of $\approx 0.5m$. The waveforms have been recorded with 8 piezo-sensors in 3-10 m distance. Preliminary results indicate tension source components. We will discuss the estimated source mechanisms in terms of fracture-mechanical processes during the development of a tension crack.

SEISMIC MOMENT TENSOR OF WEAK CRUSTAL EARTHQUAKES OF VRANCEA (ROMANIA) RETRIEVED BY WAVEFORM INVERSION

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The inversion of high-frequency seismograms is performed to retrieve the seismic moment tensor for weak crustal earthquakes ($2.9 \le M_L \le 3.6$) of Vrancea region (Romania). The source is described by the full moment tensor, having both volumetric component and deviatoric part. Synthetic seismograms are computed by the modal summation method, using the point source approximation, for horizontally layered anelastic media. The digital waveforms recorded by the Romanian local network (velocity records, vertical component, with sampling rate of 50 samples/sec) are used. The method performs dynamic relocation of the hypocentre and a simple optimization of the structural model simultaneously with the determination of the source mechanism.

SEISMIC MODELING OF EXPLOSION EARTHQUAKES OF MT. ARENAL VOLCANO, COSTA RICA

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The seismic modeling of explosion earthquakes was made for earthquakes related to the 1991 eruptive activity of the Mt. Arenal volcano, Costa Rica, during 8 to 16 of April and 7 to 18 July. There were investigated 20 digital short-period 3-component seismic records. The simultaneous recording of sound waves had allowed to control the nature of seismic events. The synthetics were calculated for vertical force that represented a counter force of eruption (Nishimura, 1995). There is shown that the multiple forces can better model the explosion earthquake source than the single force. The best coincidence of the observed records and synthetics was obtained for a sequence of 4 or 5 vertical forces which were included consistently with an interval of 0.5 sec. The calculated counter forces of explosions were compared with the published worldwide data.

ON THE RESOLUTION OF THE ISOTROPIC COMPONENT IN MOMENT TENSOR INVERSIONS

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If it is in theory possible to solve a full moment tensor from inversion of a few seismograms, the isotropic component is often set to zero in practice in order to stabilize the inversion. We investigate under which practical conditions the determination of the isotropic component is mathematically and physically reliable. First, we examine the question from a physical point of view and show that the classical interpretation of a full moment tensor for tectonic events implies rheological constraints that are not always realistic. We propose an extended physical model which includes tectonic and non-tectonic volumetric variations. Then we use the tools of inverse theory to infer mathematical constraints on the problem of full moment tensor inversions from teleseismic spectra. In particular, we examine how much of the moment tensor can be solved, in relation with the eigenvalues of the inverse problem. The resolution and the correlation matrices show that, among a choice of possible constraints on the full tensor, a constraint on the isotropic component is most valuable. In addition to the estimation of the tectonic and non-tectonic isotropic components in full moment tensor inversions, we finally propose extensions of the basic linear methods that can lead to particular models in subspaces of interest, such as tectonic models, or decompositions in a double-couple plus a volumetric part. Some applications of our theoretical developments to regional waveform inversions are shown, for the April 1992, Roermond, earthquake.

Abstract

The main purpose of this work is to analyse global inversion of waveform data for the moment tensor and source retrieval using three component data from seismic stations. For this purpose we have extended to the SH component of motion the method preposed by Sileny et al. (1992). The main advantage of considering all three components at each recording station is to reduce the number of necessary stations and hence not only the cost of the seismic network, but also the noise introduced by the insufficient knowledge of the physical properties along the source-receiver path.

It is well known, that the source depth is poorly resolved by Love waves, whereas Love waves add information to the moment tensor components. Rayleigh waves includes information of both source depth and earthquake mechanism. The source is assumed to be a point source in space but not in time. The procedure used finds the global solution of moment tensor, source-time function, and source location. Green functions are interpolated between two extreme models of the structure, representative of the considered area. The first step retrieves the source location and the moment rate tensor components as functions of time, and in the second step, these time dependent moment rate tensor components are inverted to obtain an average constant moment tensor and a common source time function. Synthetic

RIFT-ZONE AND OFF-RIFT EARTHQUAKES IN ICELAND

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Most earthquakes in Iceland are associated with the rift zone and the off-rift ocean-ridge discontinuities, the Tjörnes Fracture Zone and the South Iceland Seismic Zone. Earthquakes in the rift zone rarely exceed M6; most are less than M5 and generated by slip on normal faults. Much of the rift-zone seismicity is associated with central volcanoes, both during and between episodes of volcanism and rifting. Most central volcanoes have shallow crustal magma chambers and geothermal fields where small changes in stress concentration or fluid pressure can trigger earthquakes. The largest earthquakes associated with the ocean-ridge discontinuities reach M7-7.5 and are generated by slip on strike-slip faults. These discontinuities are located between overlapping rift-zone segments and concentrate shear stresses during spreading in the adjacent rift segments. Numerical results indicate that simultaneous spreading in subparallel rift-zone segments gives rise to the largest earthquake sequences in Iceland.

ERROR ESTIMATE OF THE MECHANISM BY MONTE CARLO SIMULATION

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Traditional approaches to estimate the error imposed on the retrieval of the mechanism of an earthquake, its rupture history and seismic moment by a noise contamination of waveform data, rely on validity of the assumption that statistical properties of the noise are ruled by a particular distribution law, prevailingly the Gaussian one. Supposing the noise can be described by its standard deviation, its variance is transformed by data kernel of linear or linearized inverse problem into covariance matrix of model parameters describing the seismic source. This approach suffers from two drawbacks: (i) the problem is non-linear; (ii) the distribution of the noise may be non-Gaussian, or may be not known at all.

We introduce the approach avoiding both the shortcomings: the region of all the solutions expected by inverting the noisy data is constructed as a set of solutions of the inverse problem for individual realizations of noisy data. They are generated from a sample of observed noise by Monte Carlo simulation: white noise is convoluted with the observed noise sample yielding a particular realization of the noise which is random but retains the characteristics of the observed sample. This approach allows us to consider even the situations when the noise has different characteristics on individual channels to be inverted.

GEOMECHANICS OF THE EARTH'S CRUST OF THE TRANSCARPATHIANS AND MECHANISMS OF LOCAL EARTHQUAKES ACCORDING TO MACROSEISMIC DATA.

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Among basic features of a geodynamic mode of the Earth's crust of the Ukrainian Transcarpathians are tectonic compression (0,000001 units/year) perpendicular to the Carpathians, small (25 km) thickness of the Earth's crust and strong differentiation between rheological properties of rocks and the depth which is due to higt (60-80 mw/sq.m) heat flow in the mantle. These reasons determine peculiarities of the Earth's crust geomechanics and specific mechanisms of local earthquakes, in particular, sliding of the upper massive "granite" layer about the surface of the "basaltic" layer due to a strongly fractured underlayer with a reduced by 0,2-0,3 km/sec value of velocity Vp present in the lower part of the "granite" layer; this underlayer is attenuated by a thermomechanic mode, cataclasis and thermochemical processes. These peculiarities are represented in macroseismic fields by distinctive muzhroomlike configurations of isoseisms, correspondent displacements of macroseismic epicenters relatively instrumental ones, time delays and spatial migration of aftershocks, as well as other spatial-temporal characteristics of a seismic mode. The Earth's crust general structure, in particular, the surface of a crystalline basement, is also perceptible in macroseismic field characteristics.

LOW FREQUENCY SPECTRAL METHOD FOR FOCAL MECHANISMS OF WEAK EARTHQUAKES IN WESTERN GREECE

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Focal mechanisms are studied for selected weak local tectonic earthquakes of Corinth Gulf (Western Greece). The method is based on complex-valued low-frequency spectra below the corner frequency, along with theoretical Green's function spectra (calculated by the discrete-wavenumber method), which is used to invert for the time-independent components of the seismic moment tensor. No apriori constraints of a pure deviatoric and/or double-couple solution are employed. The restriction to the low frequencies disables study of the source time function, but decreases the undesired sensitivity of the method with respect to the unknown structural details. The records are processed as a whole, without any separation of the individual waves, thereby not requiring any amplitude picking. These features make the method robust enough, applicable to small networks of a few 3-component stations. The results are compared with focal mechanisms determined by other methods. Errors and uncertainties are discussed both on synthetic and real data sets.

TESTING OF THE EMPIRICAL GREEN'S FUNCTION DECONVOLUTION CAPABILITY IN THE SPECIAL CASE OF VRANCEA SUBCRUSTAL EARTHQUAKES

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Vrancea is one of the few singular seismic regions of the world where intermediate-depth earthquakes are permanently generated (around 10 events/month with $M_L > 3$) within an extremely confined focal volume. This particularity makes it like a suitable site for application of EGF technique. The purpose of the paper is to test how well the EGF deconvolution succeeds to constrain the source and to optimize its application to Vrancea earthquakes. Three main events: March 11, 1983 (M = 5.4), April 12, 1983 (M = 5.1) and August 7, 1984 (M = 5.1) located in the lower part of the subducting lithosphere (h ~ 150 km) are considered. A set of 30 events (3.0 < M < 4.4) occurred between 1981 and 1997 are selected as corresponding empirical Green's functions. The relatively large number of available waveforms allow us to test the performance of the EGF technique in retrieving the source time function and source directivity.

ROBUSTNESS OF POINT SOURCE MOMENT TENSOR RETRIEVAL IN THE ETNA VOLCANIC AREA

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We determine the complete seismic moment tensor of a set of shallow earthquakes in the Etna volcanic area (Italy) using the method developed by Sileny and Panza (1991). This method does not need an initial source model and consists of two steps: linear waveform inversion, from which the moment tensor rate function (MTRF) is retrieved and subsequent factorization of the MTRF to compute the average fault plane solution and the corresponding source time function.
As to investigate volume changes of the source related to movements of magmas and lenticular cracks connected with fluid circulation, we are interested in the temporal evolution of the isotropic and of the deviatoric component, some preliminary tests have been done to estimate the reliability of the obtained solutions. The robustness of the moment tensor solution is investigated for different structural models and for various station distributions. Advantages and limits of the method are throughly discussed.

ARE THE SOURCE PARAMETERS OF THE VRANCEA (ROMANIA) SUBCRUSTAL EARTHQUAKES DEPTH DEPENDENT?

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Vrancea intermediate-depth seismic zone ($60 < h < 200$ km) is characterized by a well-confined focal volume (the corresponding epicentral area is less than 3000 km^2). Several observations (number and size earthquake distribution on depth, fault-plane solutions) suggest that the seismic regime varies downdip the subducting lithosphere.
The goal of this paper is to outline any trend of depth dependence in the source parameters in case of the Vrancea subcrustal earthquakes. To this purpose, the Empirical Green's Function deconvolution is used on a set of more than 150 events with focal depth covering the entire intermediate-depth range. The major shocks of August 30, 1986 ($M_w = 7.2$), May 30, 1990 ($M_w = 6.9$) and May 31, 1990 ($M_w = 6.3$) are also considered.
Possible trends are tested relative to the random fluctuations. Finally, correlation with seismic cycle modeling for Vrancea region is discussed.

FOCAL MECHANISM DETERMINATION IN ANISOTROPIC MEDIA: NUMERICAL STUDY

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Properties of seismic waves in anisotropic media and implications to seismic wave inversion for determination of focal mechanism are studied. The study comprises an inversion with P waves only, and with P and S waves together. By numerical modelling we quantify errors induced by using an incorrect structure model. In particular, we concentrate on errors induced by using an isotropic model instead of a true anisotropic one. We evaluate a range of anisotropy for which effects of anisotropy in focal determination are negligible. We discuss limits of applicability of standard inversion techniques for region where weak anisotropy is present, which is a quite common situation in many areas.

COMPARISON OF OBSERVED SECULAR VARIATION WITH THE CHANGES OF THE IGRF IN GERMANY

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In 1965, 1982 and 1992 repeat measurements of the magnetic field at selected stations have been made in the Federal Republic Germany. From them approximative polynomials for the secular variation were calculated for the intervals 1965 - 1982 and 1982 - 1992 and compared with the IGRF changes:

1. The signs of the changes of the measured regional field and of the IGRF are identical for the linear and for the quadratic terms. The quadratic terms of the regional field changes are about 2.5 times larger than the respective IGRF terms, the linear terms 1.5 times larger. Consequently, the secular variation is included (only) partly in the IGRF.
2. The mean north-south gradient has increased from 1965.0 to 1982.5, afterwards decreased. The east-west gradient and the quadratic terms have retained their signs. The increase of the main field since 1982.5 is much smaller than before.

As the source of the secular variation is suspected in the core of the Earth, core field contributions become visible here which are included in the IGRF only partly. The strong and areally small changes imply that for some substantial processes within the core the time constant is in the order of decades. This indicates similarly fast temperature changes at the core-mantle boundary.

CORRELATION OF ANOMALOUSLY HIGH b-VALUES WITH MAGMATIC ACTIVITY

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By mapping the b-value of the frequency-magnitude relationship in three-dimensional grids with node spacing of less than a kilometer, we show that about 80% of the seismically active volumes under volcanoes show normal b-values ($b \leq 1$). The rest is occupied by small volumes ($r \cong 1$ km)of anomalously high b-values ($b > 1.3$). This means that the average earthquake size in the anomalous volumes is clearly smaller than in the normal crust. This can be explained either by greater heterogeneity or lower effective stress in the anomalous volumes. The volumes with anomalously short crack size (high b) correlate with the location of magma chambers at the following volcanoes investigated so far: Mount St. Helens, Mount Spurr, off-Ito volcano and Long Valley caldera. In two locations, pronounced increases of b-values from 0,8 to >1.3 as a function of time with progressing intrusions could be documented in volumes of about 5 km radius. The simplest explanation of this observation is to assume that an increase in pore fluid pressure took place, because the alternative, an increase in fracturing (heterogeneity), should not be a unique occurrence in a volcano that has existed for thousands of years, and the affected volume seems too large. We conclude that detailed mapping of b-values can aid in defining active magma bodies.

SE28 Open session on volcanology, geochemistry and petrology

Convener: Jakes, P.

SURVEYING THE VESUVIUS BY TRANSIENT ELECTROMAGNETICS

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In April 1997 a two week long-offset transient electromagnetics (LOTEM) survey was conducted at Vesuvius. LOTEM is an active method designed to determine resistivity distributions down to a penetration depth of approx. 15 km. 23 stations, each equipped with a magnetic and an electrical field sensor, were set up on a profile of 10 km length. The main aims of this first LOTEM application on an active volcano were the analysis of the specific conditions in volcanic environment and the investigation of the conductivity structure of Vesuvius.

One particular aspect for measurements on volcanoes is the strong topography. We tried to simulate the influence of topography using 3D modelling. Another feature of the data is the strong distortion by powerline noise. The signal to noise ratio was significantly improved using new digital filters. Finally we obtain a model of the conductivity structure of Vesuvius derived from LOTEM data. The 1D inversion results show a good conducting layer in depths of 0.5 to 2 km below the surface. It is still an open question whether the low resistivity is caused by melts or by fluids.

WAVE FIELD ANALYSIS OF THE SEISMIC NOISE AT THE MT. VESUVIUS, ITALY, APPLYING ARRAY TECHNIQUES.

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Several experimental evidences have shown the validity of array techniques, as frequency-wavenumber spectral analysis and correlation method, to localize seismic noise sources and to infer the volcanic surface structure. In this study the volcanic noise has been recorded at the Mt. Vesuvius, Southern Italy, by three portable eight-channel arrays, consisting of two three-component and eighteen vertical 4.5 Hz, extended up to 1 Hz, geophones distributed on a 500x500 metres area, about 1 km far away from the summit crater. Two-dimensional spectral techniques applied to the noise allow to obtain the back-azimuth and the apparent velocity of the plane wavefront and, consequently, to localize the noise sources. The correlation method allows to infer the dispersion relation of the surface waves composing the noise and hence the shallow velocity structure of the investigated medium. The obtained results have been compared with the prevoius ones showed by other authors and provide good constraints for the knowledge of the volcanic structure.

TECTONIC SIGNIFICANCE OF Nd, Sr AND Pb ISOTOPIC COMPOSITION OF CENOZOIC MAGMATISM IN THE AEGEAN AREA

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Nd, Pb and Sr isotopic compositions were determined from igneous rocks representing the wide geochemical, spatial, and temporal range of post-collisional late Cenozoic magmas in the Aegean area. Most magmas result from partial melting of sub-continental lithosphere. Isotopic variation is due to: (a) Proterozoic subduction-related enrichment in Th, U and LILE, yielding distinctive Pb isotope composition; (b) Mesozoic subduction of marine carbonates and of terrigenous sediments from both the proto-Nile and Hercynian basement; (c) an asthenospheric component in some south Aegean magmas. Thermal effects of rapid Cenozoic extension led to melting of subcontinental lithosphere producing shoshonitic magmas in the north Aegean. Slab break-off and intrusion of hot asthenosphere caused partial melting of rift-related continental margin basalts to generate adakitic magmas. Further outboard, mafic magma from enriched lithospheric mantle melted thickened lower crust to produce granitoid plutons of the Cyclades. The South Aegean arc results directly from subduction-related magmatic processes interacting with extension.

GOLD-BEARING QUARTZ - AMPHIBOLE - CARBONATE METASOMATITES AT THE SURSKAYA STRUCTURE (UKRAINE) - EVIDENCE FOR PRE-METAMORPHIC GENESIS.

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Gold-bearing quartz-amphibole-carbonate metasomatites are widespread within the Middle Pridneprovye granite-greenstone province. Recent petrological and geochemical studies allow conclusions about the pre-metamorphic origin for alteration and relative gold mineralization. Considered to be metamorphic green amphiboles overlaing not only quartz-carbonate and chlorire-biotite alteration paragenesises, but colourles amphiboles of initial metabasites. Amphiboles composition in all zones is dependent of the precursor rocks composition. Metasomatites formed during solfataric-fumarole and hydrothermal activity time, while greenstone volcanogenic-plutonic complexes were emplacing. Pre-metamorphic gold-bearing metasomatites genesis supposes the near-surface formation for the part of ore veins, which later underwent metamorphic reorganization and partial redistribution of the metallic substance under the conditions of higher temperature and reduction.

CLASSIFICATION OF VOLCANIC ROCK SERIES: AN EXPERIENCE FROM THE KAMCHATKA ISLAND-ARC SYSTEM

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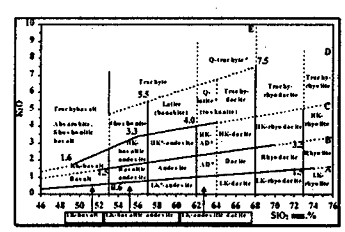
Island-arc, transitional and riftogenic groups have been identified among volcanic series of the Kamchatka island-arc system, on the basis of Ti, P, K, Na, Ta, Nb,
Zr, Hf, U, Th, TR, Y, Ba, Sr, Rb, Ni, Cr concentrations. The island-arc group (fig.)
includes low-K (A), middle-K (B), high-K (C), and shoshonite-latite (D) series. The K-alkaline series(E) reflects a postsubductional setting. Classification was performed using the K_2O-SiO_2 diagram, modified after Nicholls & Carmichael (1969), Jakes &



White (1972), McKenzie & Chappell(1972), Peccerillo & Taylor (1976), Jill (1981), Evart(1983),Bogatikov(1985) et al. with regard to the rock systematics from "Classific. of igneous rocks..." (1989). Abbreviations in the figure stand for: AD* - andesitic dacite, Q* - quartz rocks.

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FACIAL ANALYSIS AS A BASIS FOR GEOLOGICAL MAPPING ANCIENT VOLCANIC EDIFICE.

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Geological mapping in the regiones of ancient volcanic activity is impossible without uaing facial analysis. This appoach give possi-bility to reconstract ancient volcanic edifices, to establish centres of eruption and volcanic vents in which very often are ore deposits. Among many volcanic facies (genetical groups) the following three are the most important: subvolcanic, vent-effusive and py-roclastic. Subvolcanic group is transitional from plutonic to vo-lcanic conditions; these are dykes, stocks, laccolites etc. Their specific fetures are: fluidal texture, brecciformity, mandelstonity etc. Vent-effusive group is especially important. These are necks, breccia chimneies, forming by lava and breccia. These rocks are usually intensively hydroyhermal changed. Pyroclastic group is represented by different tuffs and breccia. These rocks were formed by explosion and so melt was rich in fluids. This is favorable for different mineralization formation.

SEISMIC TRAVEL TIME TOMOGRAPHY STUDIES OF TWO VOLCANOES, THE LONG VALLEY CALDERA, CALIFORNIA, AND THE HENGILL VOLCANO, ICELAND

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The Long Valley caldera, located on the edge of the Sierra Nevada in east central California, is one of the largest active rhyolitic volcanic systems in the world. Situated in a completely different environment, the mid-Atlantic Ridge insouthwest Iceland, is the Hengill central volcano. In both regions the P- and S-wave velocity structure has been examined to depths of 12 km below sea level, using travel times from local earthquake and controlled source data. Despite the vast difference between the study regions, the resulting velocity models have some common features. Neither of the volcanoes show any pronounced simply-connected low-velocity S-wave bodies. Instead, reduced P-wave velocities control the top 12 km of the crust beneath the centers of eruption. Though volcanically active in the last few thousand years, this indicates that neither of the volcanos have a large discrete magma chamber. The low P-wave velocities might instead indicate hydrothermal activity and the presence of supercritical fluids deep in the crust.

SE29 Continental roots: their petrology, geochemistry and geophysical features

Convener: Jakes, P.
Co-Convener: Dragoni, M.

Mantle Hybridism -Result of Mixing Between Melted Mantle Metasomatites and Hot Plum Basalts.

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An example of high temperature hybrid pyroxenite Vitim xenoliths allow to reconstruct the creation processes for green low Cr series common in continental mantle sampled by alkali basalts and kimberlites. This essentially websteritic rocks reveal two separate groups with the rapid decrease of Cr content and calculated temperatures from 1400 to 1250oC Simple binary mixing of 5-10% degree fractional melts from ferriferous metasomatic lherzolites with the melt in equilibrium with the most primitive high temperature basaltic cumulates well describe their trace element behavior. More flat then basaltic cumulates trace element patterns and elevated HREE content suggest selective Gar melting and mixing instead of primitive melt origin. Deep Ta and Nd depressions in one group and small positive peaks in other's suggest assimilation of ilmenite-bearing metasomatites and then early and essential separation of ilmenites. Irregular behavior of LILE- HFSE components suggest reactional relationships with Phl and possibly Amph. Picrite melt (mg'>75) original for this group should be formed at the head of the rising plum magma as a result of the heat impact of intruded hot masses on the frontal part of mantle metasomatites. Restricted volumes of mixed melt portions allow to form motley rock series with exotic trace element patterns. This rocks may give the key for the origin of some Ca-rich picrite magmas and to serve as example of the analogic processes for the plum interaction with continental keels of cratons. (Supported RBRF grants 94-05-17103 and 96-05-66049).

SUBCRUSTAL TEMPERATURES IN PRECAMBRIAN CRATONS: A COMPARATIVE STUDY

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The goal of the study is to use heat flow constraints to estimate temperature distribution in the crust and Moho temperatures in different Precambrian regions of the world. The estimates are based on the steady-state solution of thermal conductivity equation for the lithosphere and are primarily constrained by surface heat flow observations (the global compilation of H.Pollack), estimates of crustal structure (the global database of W.Mooney) and the associated distribution of thermal parameters within the crust. Where necessary, paleoclimatic corrections to heat-flow data were made. A broad study of the available data on heat generation in crystalline and sedimentary rocks of different Precambrian provinces of the world was carried out to make a reliable constraints on heat production distribution with depth, using the concept of "heat flow provinces". A set of maps for temperature distribution at the base of the crust was produced for the Precambrian platforms of Europe, Asia, Australia, and Africa. The results of the study show that Moho temperatures in the ancient continental provinces can vary in wide limits: from less than 300oC beneath the oldest parts of the Siberian Platform and the West African Craton to more than 700oC in the Parana Basin, with the most typical values being in the range of about 500-600oC. A good correlation was found between subcrustal temperatures and Pn seismic velocitieas.

Melting Processes in Trans Baikal Mantle.

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For series of lherzolite xenoliths in the alkali basalts from Baikal Rift Zone degree and proportion of the melted phases were determined using published and new TREE analyses of bulk rocks, and minerals (SIMS and ICP MS). For garnet lherzolites from Vitim the degree of melting vary from 0.7 to 1.25%, being higher - 2-4% for spinel lherzolites. Usually Gar and Cpx demonstrate the equilibrium but in several samples the difference, sometimes essential, was found. Melts parent for the Gar are enriched in LREE and HREE and reveal Ce negative peaks comparing with melts parent for the clinopyroxene. Melting ensembles for garnets are Cpx-Gar enriched. The peculiarities found for melting phases suggest their reactional relationships and repeated fusion. TREE patterns of garnets are similar to that obtained experimentally from carbonatite melt (Sweeney et al.,1995). Crystallization of minor Ce-carbonates or phosphates can explain Ce anomalies. Differences in LREE between determined and calculated from the minerals bulk rock TREE compositions is well covered with the 1.5% partial melts crystallized in intergranular space. These features suppose that usually mineral phases are growing from the thin films of the volatile- enriched melts what can also explain the variations and zonation in trace element composition. The geometry of melts supposed to be dependent from the volatile content and degree of melting and vary from one melting/ percolation stage to another. Essentially hydrous melting may brings to the Opx growth, carbonatite or CO2- dominated - to the silica undersaturated Gar-CPx assemblages, the intermediate - to the modal melting. For Hamar-Daban (data Ionov et al., 1995) 0.3-0.8% degree and enriched in Ol melting assemlbage is found supposing hydrous fluid as agent. For Bartoy lherzolites the degree of melting is about 1% being one order less for the metasomatites. (Supported RBRF grants 94-05-17103 and 96-05-66049).

Melt Differentiation in Mantle Vein Systems. Repeated Dissolution and Precipitation.

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Precise ICP analyses for the various pyroxenites from Vtitim picrite basalts allow to reconstruct quantitative phase relationships and the process of differentiation of their parent magmas with the simulation of natural trace element distribution. In studied groups of pyroxenites: black megacrystalline suite (BMS), hybrid HToC green pyroxenites (GHTP), hybrid LToC veins (HLTP) and Cr-diopside veins (CDV) pulsing character for Pb, HFSE, and sometimes Zr- Hf was detected. BMS demonstrate not only the perfect fractional cotectic (CPx-Gar) differentiation but also dissolution of the earlier formed phases. It is pronounced at the ilmenite bearing group near 40% of remaining liquid. The process branches in this stage with the appearance of the free fluid phase, producing cavities filled with the ilmenite and Ti-biotite. Calculations show the dissolution of ilmenite and possibly minor rutile and zircon from the early cumulates. Such pulsing precipitation-dissolution process suggested to be the principal factor of the ore rare element component enrichment in pegmatite- like mantle and possibly crust processes. Ilmenite rounded blebs are coated by the glass films crystallized from fluid suggested to be the main transport mater. Repeated fusion of restites explains the mirror like patterns of the HLTP which effectively dissolute the wall matter due to enrichment of melts in volatiles while continuos Gar precipitation is responsible for the depletion in HREE. CDV pyroxenites also reveal remelting origin. Their calculated melting ensemble is much more Gar and Cpx enriched with higher degree of melting which brings to the appearance of more rounded and HREE depleted then for lherzolite Cpx REE patterns. (Supported RBRF grants 94-05-17103 and 96-05-66049).

GEOPHYSICAL EVIDENCE OF MANTLE INVOLVEMENT IN PALEOPROTEROZOIC OROGENESIS

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Electromagnetic data from western North America shows compelling evidence for chemical structure created in the mantle during the Paleoproterozoic East Alberta orogen. The Paleoproterozoic was a period of tremendous tectonic activity on a global scale, the effects of which are still not completely understood. In western Canada, the spatial correlation of mantle conductivity structure with the isotopically defined age provinces in the upper crust is suggestive of subduction related metasomatism that substantially polluted the subcontinental mantle during the orogeny. This talk will present the geophysical and geological evidence used to identify the collision event and develop the correlations that indicate the mantle and crustal processes were related.

MELTING OF THICKENED CONTINENTAL CRUST BY THE PASSAGE OF BASALTIC DYKES

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Thickened continental crust is thermally perturbed on account of the increased vertical scale over which radioactive heat generation occurs. Geotherms in thickened crust rise to shallower depths than in normal crust, and the temperature at the base may approach the solidus of the rocks. In consequence basalt intrusions from the upper mantle are unlikely to cross this warm zone without causing melting of crustal rocks. Extensive mixing may subsequently occur between basalt and crustal melts.
A geological example of this process is the Neogene to recent post-orogenic volcanism that took place on the northern part of the Tibetan Plateau. Seismic data indicate a thickness of $\sim$ 70 km for the crust beneath the Plateau. In some places large volumes of silicic melts have been produced and the chemical signature of much of the erupted magma suggests a crustal origin. Values of SiO_2 range from 55 % to 65 % and the content of K_2O + Na_2O is greater than 6 %.
We present a physical model of heating from the side of a block of solid in which there is a vertical temperature gradient. The aim is to predict the depth at which melting is likely to take place due to the passage of mafic dykes through the crust, and to determine the initial geometry of the molten region and the rate of melting.

MODELLING OF INTRACRUSTAL GEODYNAMICS UNDER COLLISIONAL BELT CONDITIONS (NE PART OF THE BALTIC SHIELD AS AN EXAMPLE)

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On the basis of geological-geophysical data interpretation and mathematical modelling, the geodynamics regimes responsible for the formation of the Lapland Granulate Belt located in the intracratonic collision zone were reconstructed. The uplifting of lower crust rocks to the surface is accounted for by a high pressure arising in ductile zones below and at junctions of mobile geoblocks. The sliding blocks impulses were short and discrete. Underthrusting resulted in backward mass flow in the crust asthenolenses as well as in ductile layers situated in the junction zone between the geoblocks, where at sertain regimes the upper crust rocks were removed to the lower crust level. Thermomechanical effects accompaning these phenomena caused excess heating of the ductile rocks and were responsible for the occurrence of intracrustal local thermal anomalies stimulating acid magmas generation, the high-temperature metamorhpism and tectonic dislocations in the rigid upper crust level. An interdependency between the parameters of geodynamic processes (velocity and direction of underthrust, ductile layer thickness,
suture dip, blocks wrap, pressure gradient in the collisional zone) at a given time span determined the velocity and direction of mass transfer, P-T variation and the formation of transform thrust zones.

THE ABSENT LOWER CRUSTAL CONDUCTOR

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In Phanerozoic regions the conductance of the lower crust is typically 200-500 Siemens and Precambrian regions 20-200 Siemens, whereas a dry lower crust should display a conductance of less than 1 Siemens. Various hypotheses have been proposed over the last three decades to explain this observation, with the two currently most promoted being saline fluids and an interconnected thin grain-boundary carbon film, but both have significant objections.
Recent studies on the southwestern corner of the Slave craton in northwestern Canada yield a conductivity-depth structure that is so far unique. Inversions of the magnetotelluric responses show that at this location, which hosts the oldest dated rocks on Earth at 4.126 Ga, there is no conducting lower crust. The conductance of the whole crust is 1.5 Siemens, and below 5 km is less than 0.8 Siemens, consistent with the laboratory studies. This suggests that processes active in the late-Archean and younger, which resulted in the emplacement of conducting material (whether fluids or solid phase) deep within the crust, were not active in the early to middle Archean as the Slave craton was being formed. There is an order of magnitude increase in electrical conductivity at a depth corresponding to the seismically-imaged crust-mantle boundary at 35 km. This observation, of the electrical equivalent of the seismic "Moho", is a first. However, to be explained is that the lithosphere immediately below the Moho is more conducting than both oceanic uppermost mantle and results from laboratory studies on mantle rocks.

GEOLOGICAL AND GEOPHYSICAL PECULIARITIES OF THE ANABAR SHIELD CRUST LIKE AN EXAMPLE OF EXPOSED LOWER CONTINENTAL CRUST

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For the area of Anabar Shield (East Siberia) we investigated geology, seismic, gravity and thermal fields. The Earth crust of the Anabar Shield presents a relict of most ancient sialic cover of the Earth including both magmagene and sedimentogenous rocks. Lower crustal complexes of Anabar Shield are identified and subdivided into passive (terranes) and active (collision zones) tectonic unites. On the present surface of the Shield we may observe lower crustal complexes uplifted to the Earth surface through tectonic processes. In that case the rock peculiariaties expected include high grade metamorphysm, high density,low heat production and some others. Gravity field of the crust within Anabar Shield is characterized by linear maxima which coincide with zones of granulitic terranes. From seismic data (Vp and Vs waves) we got the fine structure of Anabar Shield crust and adjacent blocks. Seismic data shows vertical and lateral inhomogenity of the Shield's crust. Thermal field of the Anabar Shield is characterized by very low heat flow density - 20 to 25 mW/m2. In Anabar area we have stable from the Early Proterozoic time lithosphere with deep "roots". For the Anabar Shield average crustal heat generation is 0.36 mkW/m3 and corresponds to the magnitudes typical for the lower continental crust. We have "frozen" crust with eroded granite-gneissic layer. The present-day crust being a possible model for the consideration of the lower continental crust consisting of the blocks reflecting collision nature of the Anabar granulites due to intense overthrust movements.

SUBCONTINENTAL DOWNWELLING: THE ROOTS ARE UNSTABLE

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One of the most fundamental of the many outstanding issues in global geodynamics concerns the role of the continents in the convective circulation that maintains the plates in their relative motion. A conventional view is that their role is essentially passive. This cannot be entirely true if only because their presence appears to account for the "one-sided" nature of subduction compared with the "two-sided" nature of seafloor spreading. There are also indications, however, that the mantle convective circulation could be significantly organized by the presence of the continents. We have recently argued (Peltier et al. 1992, Pari and Peltier, JGR, 101, 28105, 1996) that there is convincing evidence for the presence of strong downwelling flow beneath the continents, flow that is driven by the presence of high density "roots" in the sub-cratonic mantle. That these roots, the classical "tectosphere", must be dynamically active has been inferred on the basis of the large free air gravity anomaly that exists over the Laurentian craton which forms the nucleus of the North American continent. In this paper we revisit these arguments and in particular demonstrate using seismic tomography controlled models of the mantle convection process that the reason why the North American craton is unique in this regard has to do both with the magnitude of its root and the fact that the flow in the mantle beneath the root is relatively uninfluenced by lower mantle density heterogeneity. We provide strong evidence that essentially all cratons are located in regions of upper mantle convergence.

THE DEVELOPMENT OF CONTINENTAL ROOTS: A NUMERICAL UPPER MANTLE DECOMPRESSION MELTING MODEL

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Decompression melting in a upper mantle continental system is studied with a numerical model. The density of the residue decreases upon melting and induces a positive buoyancy force which enhances the stability of continental roots over long periods of time. In previous work we have shown that the compositionally distinct continental root can grow steadily through ongoing mantle differentiation by means of decompression melting in small scale diapirs. The present model incorporates a more realistic melting phase diagram showing an increase in the slope of both the solidus and liquidus. Furthermore, the difference between solidus and liquidus temperature decreases with depth and a non-linear isobaric melting parameterization is used. The model includes a consistent recurrent melting mechanism, which requires a high (kilometer scale) spatial resolution of the numerical mesh. In addition, p, T-dependent viscosity, depth and time dependent radiogenic heating as well as viscous heating are incorporated. The resulting model can be applied to situations in which deep melt formation occurs. This is important since the depth interval over which melting occurs has decreased during the Earth's history.

SE30 Degassing of high-level magma chambers and the evolution of magmatic-hydrothermal systems

Convener: Fulignati, P.
Co-Convener: Carroll, M.R.

EARTHQUAKE-INDUCED CHANGES IN THE ISOTOPIC COMPOSITION OF THE WATER IN THE GEOTHERMAL RESERVOIR AT VULCANO ISLAND, ITALY

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A geothermal reservoir formed near the foot of the active crater of Vulcano Island mainly by condensation of magmatic vapor. Increases in the oxygen composition of the reservoir water are consistent with earthquake-induced increases in the contribution from $\delta^{18}O$-rich magmatic condensate to the geothermal reservoir. Subsequent ^{18}O exchanges during reactions between the highly reactive magmatic condensate and the local rocks at the temporarily increased reservoir temperature cause the reservoir water to shift to lighter ^{18}O values. These variations in the oxygen composition of the reservoir water are not reflected by the deuterium composition, as the δD value of the magmatic condensate released from the magma after the tectonic earthquakes approaches values very similar to that of the water in the geothermal reservoir.

Evolution of trace elements in fumarolic gases at Vulcano Island (Italy)

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The development of improved sampling methods and analytical techniques for the determination minor and trace elements in volcanic gases during the last year lead to identification of indicators for volcanic activity. The knowledge of their distribution contributes significantly to a better understanding of degassing processes from various sources. Among the various alkaline solution tested, the best results have been obtained by means of Ammonia solution. A large number of minor and trace elements was determined by application of NAA, HPLC, ICP-MS and AAS.
Samples of volcanic gases have been collected by means of alkaline absorption solutions at the crater fumaroles of Vulcano island.
The good correlation between some trace elements and halogen suggests halogenidric acids act as carrier for these elements. Furthermore, their anti-correlation with both He and CO_2, well agree with current models about the genesis of these fumarolic gases, coming from a mixing between magmatic and hydrothermal gases. Our results also suggest that other processes could sporadically contribute to the abundance of trace elements in fumarolic gases.
Moreover, according to the modification in the hydrothermal solution, suggested by Di Liberto et al. (1998), a decreasing metal and halogen contents have been observed during the last few years.

PRE-ERUPTION VOLATILES IN AD 79 MAGMA CHAMBER OF VESUVIUS (ITALY)

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The results of a study of volatiles in groundmass glasses and in melt inclusions (MI) in sanidine, leucite and diopsidic pyroxenes from phonolitic "white" and tephri-phonolitic "grey" pumices of the AD 79 eruption of Vesuvius give insights on magma chamber evolution and on its pre-eruptive state.
Volatiles in MI were determined by FTIR spectroscopy (water and CO2) and EPMA (chlorine and sulfur). Sanidine is an ubiquitous phase in AD 79 products. On the basis of their isotopic features and mineral chemistry we can state that sanidine crystals in grey pumices result from syn-eruptive mixing between an overheated, crystal free, tephriphonolitic magma and a phonolitic "white" liquid. A mean water content of about 6.5 wt% can be assumed for the phonolitic magma, suggesting a minimum pressure around 150 MPa.CO2 and S are always under the detection limit. Cl is very close to the experimental solubility limit. Water content of MI in sanidine from grey pumice is generally lower than water from "white-hosted" sanidine, and their composition is more evolved. Sanidine resorption due to the heating effect during syn-eruptive mixing can be invoked to explain these differences. Groundmass glasses are characterised by very high Cl content (8000-8500 ppm). The Cl melt-fluid partition coefficient result to be lower than that for rhyolitic compositions, resulting in a low Cl yield to the atmosphere during eruption.

THE INFLUENCE OF INTRATELLURIC FLUIDS ONTO SUBMARINE VOLCANIC, HYDROTHERMAL AND SEDIMENTARY PROCESSES

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In the metalliferous sediments accumulated within the East Pacific Rise axial parts and flanks near 13°N and 21°S submarine hydrothermal systems were identified "primitive" basalt minerals together with chromepicotite, chromediopside, periclase, carborundum, native metals and intermetallic combinations (intermetals), magnetite - chromite balls with native Fe nucleus, basaltic glass with quarts-hydromica-chlorites nodules. The intermetals were sampled also from hydrothermal plumes. Their simultaneous detection testifies that they are genetically akin. Formation of carborundum, intermetals (especially native Al, Zn) needs dry, sharply reductive conditions and the low partial pressure of oxygen. These conditions are realized at basaltic magma metallization by the intratelluric fluids (H_2, CH_4, CO). The intratelluric fluids penetrating about fracture zones on the flanks are favourable for the initiation of low-temperature hydrothermal activity. If low-temperature solutions discharge near oceanic floor surface amorphous "nontronitic" and Si-Fe mud are deposited. When the fluids discharge within sediments the metasomatic processing takes plase. The low-temperature hydrothermal activity was not identified on the flanks at the 21°S area. The EPR high-spreading areas (21°S) my be though considered as zones of "focussed" fluid streams in contrast to zones of "scattered" fluid streams (13°N).

Variations of fumarolic gases composition at Vulcano island (Italy) related to hydrothermal system evolution.

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There is a general agreement among reseachers about the genesis of fumarolic gas of Vulcano crater, considered as a mixture of magmatic and hydrothermal fluids.
The mixing model proposed by Nuccio et al. (1998) is able to quantitatively evaluate composition and mixing fraction of the two components. Our investigations indicate a remarkable decreasing trend of both HCl and total sulphur in fumarolic gas, over the last 20 years. This clearly suggests important modifications underwent in the hydrothermal system, as both gases are mostly released from it. Although a remobilization process of solid phases has been recognized, we suggest that a composition change of hydrothermal solution is the main process inducing the observed composition trend. Particularly, we interpret the above changes as the consequence of a decreased Ca^{2+}/Na^{+} ratio in the solution, and a related pH increase affecting the production of acidic gases. Our results also suggest the generation and expansion of a central vapor monophase zone in the hydrothermal system, having important implications on possible magma-water interaction and on phreato-magmatic explosion hazard assessment.

RARE EARTH ELEMENTS BEHAVIOUR IN THE ALTERATION FACIES OF AN ACTIVE HIGH-SULFIDATION HYDROTHERMAL SYSTEM (VULCANO, AEOLIAN ISLANDS, ITALY)

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La Fossa volcano is an example of an active magmatic-hydrothermal system. Acid gases in part of magmatic origin (HCl, HF, SO_2), linked to the degassing of a shallow magmatic reservoir, contribute to the high temperature (up to 500°C) fumarolic fields present at La Fossa. A high-sulfidation system develops at the surface, producing silicic, advanced argillic and intermediate argillic alteration facies. In the subsoil, laterally to the conduit zones, a neutral low permeability hydrothermal system develop. Many works have proved that REE can be mobilized in hydrothermal environments under low pH conditions, high water/rock ratio and abundance of complexing ions. Their behaviour can therefore be used to characterize the hydrothermal processes. In this work the REE contents of the hydrothermally altered rocks are compared to the unaltered rocks, and the REE behaviour in the hydrothermal processes is discussed. REE appear to be strongly depleted in the silicic alteration as a result of the very low pH conditions of the hydrothermal solutions and their high content in complexing ions. In the advanced argillic facies LREE concentrations do not change in respect to the unaltered rocks, while HREE are depleted. This may be due to the abundance of alunite group minerals, which retain LREE. In the intermediate argillic facies the higher pH conditions determine the immobility of the REE. Indeed, the REE concentrations are sometimes slightly higher than in the unaltered rocks, possibly as a consequence of the abundance of phyllosilicates, which can retain REE. Propylitic and phyllic alteration in the subsoil are characterized by REE immobility, due to the nearly neutral pH conditions and to the low water/rock ratio.

A MELT INCLUSION STUDY OF VOLATILES DURING THE 1944 LAVA FOUNTAINING ACTIVITY AT VESUVIUS

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A study of pyroclastic deposits, representative of the sequence of lava fountaining activity occurred during the 1944 eruption of Vesuvius, has been done. Although the whole rocks vary in composition from phonotephrite to tephrite from the bottom to the top of the deposits, the separated groundmasses exhibit a homogenous phonotephritic composition. Tephrites result from the accumulation of clinopyroxenes.
The mineralogy indicates two distinct parageneses: a) olivine (Fo89-83) + diopside; b) salite + olivine (Fo70)+leucite + plagioclase. Similarly, the melt inclusions exhibit nearly primitive tephritic composition (Mg#0.66, CaO/Al2O3 = 0.88), rich in volatiles (S = 0.23-0.20 wt%; Cl =0.50-0.56 wt%, H2O up to 3 wt%; CO2 = 2150 to 3000 ppm, with one measurements at 4000 ppm), to evolved phonotephritic composition (Mg#~0.44; CaO/Al2O3 ~ 0.5), rich in Cl (0.8-1.0 wt%) but depleted in H2O (<1.0 wt%), and CO2 (between 1400 and 280 ppm). The mineral paragenesis of the phonotephrites represents low pressure crystallization (Pfluid = 50-150 MPa). Olivine, diopside and their melt inclusions indicate higher pressures of fluids (300-600 MPa), the ascent of magma from deep reservoir(s) and its injection in the shallow one just prior to the eruption. The involvment of this CO2. H2O-rich magma after the partial emptiyng of the shallow reservoir causes the transition in the eruption dynamics from lava effusions to strong lava fountaining.

PALAEOHYDROGEOTHERMAL SYSTEM OF AVALA MOUNTAIN (NEAR BELGRADE) IN RELATION TO MAGMATISM AND ORE-FORMING PROCESSES

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Avala mountain is located about 15 km south of Belgrade. Geological investigations and prosection in Avala and its surroundings started a long time ago, mostly due to mercury, lead and zinc deposits. Mercury mine "Suplja stena" is probably the oldest mine in the world well known from ancient time. Besides ore deposits in the Avala area is located nine occurrences of mineral deposits consists of siliceuosus sinter and six occurrences of carbonate deposits formed of calcite, siderite and dolomite. Hydrogeothermal altered minerals: quartz, calcite, zeolite etc. are discovered in five boreholes at depth from 40 to 80 m in neogene sediments and bellow them in bedrock consists of serpentinite. The mercury ore deposits are discovered in siliceuosus sinter. The galenite ore deposits are discovered in carbonate rocks. The temperature of hydrogeothermal fluid which was forming the carbonate occurrences were 100-150 oC according to homogenization of inclusion. Siliceous occurrences were formed from fluid with the temperature of 200-275 oC. The origin of the hydrogeothermal convective system is undiscovered granitoid intrusion of neogene age. Active discharge of fluids stopped, according to paleontological proves at the end of pliocene and beginning of quaternary.

Composition changes of volcanic gas and computation of magma ascent

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Volcanic gases provide powerful information on magma degassing process, as their amount and composition are related to the thermodynamical conditions under which they have been released. Unfortunately, they could interact with hydrothermal systems before they are able to reach the surface. In this case, variations of gas composition are difficult to interpret, as mixing process could masks the actual changes of each component. We developed a geochemical model, based on mass and energy balance equations, to rigorously and quantitatively evaluate composition and fraction of magmatic and hydrothermal components involved in mixing process. Then, we are able to quantitatively assess magma depth and ascent, by improving the approach proposed by Nuccio & Valenza (1992, 1998). In fact, the appropriate use of helium isotope and gas composition, solubility of volatiles and their partition constants between melt and vapour phase, allows to compute both depth and ascent of magma. The mass involved in the process can be also estimated taking into account the computed magma rise, the excess of released volatiles, their solubility.
Small magma movements towards the surface yield large changes in gas composition and small variations of volatile outputs. Therefore, geochemical parameters are extremely sensitive tracers of magma ascent, suitable for volcanic eruption forecasting.

CRYSTALLIZATION INDUCED BY DEGASSING: EXPERIMENTAL DATA AND IMPLICATION FOR THE MAGMA CONVECTION AND FLUID TRANSPORT.

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Generally convection in a magma chamber is considered as thermal. double-diffusive or recently as phase convection due to solid phase formed at cooling. However, probably decisive role in the convection pattern formation in the shallow level magma chambers has fluid release at slow degassing. At systematic analysis from the classical nucleation theory viewpoint it is shown that homogeneous nucleation of fluid bubbles in acid melts it is not expected at the initial water contents below about 3 wt.%. Problems with nucleation lead to the nonlinear features such as degassing fronts as found in the experiments on the decompression of granite melt with 5.5 and 7 wt.% of initial water content. Degassing causes crystallization of the melts close to subliquidus conditions while growth of solid phase facilitates heterogeneous nucleation of bubbles. Experimental data on the obsidian and ore bearing Li-F granite melts crystallization at decompression are presented. It is demonstrated on the numerical model that coherent motion of fluid and crystal phases at degassing in the narrow top zone of shallow magma chambers can provide quasi-steady state convection mode.

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SULFUR CONTENT OF APATITE TRACKING MAGMA DEGASSING: EVIDENCE FROM THE YERINGTON PORPHYRY COPPER BATHOLITH, NEVADA

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Crystallization during cooling of the ~100 km^3 Luhr Hill granite, the last intrusion of the Yerington batholith, lead to saturation in magmatic aqueous-chloride fluids rich in alkalis, metals, and sulfur that caused porphyry copper mineralization. The Luhr Hill now contains 14 to 49 ppm sulfur, but lost >1000 ppm sulfur (SO_2»H_2S) to the hydrothermal fluid during degassing. Yerington apatite contains 1.39-0.02 wt.% SO_3, between 0.84-0.0 wt.% Cl, and are fluorine-rich (F/(F+OH+Cl)=0.6 to 1.0). X-ray maps of apatites indicate sulfur zonation typically with high-S cores, often with concentric zonation, and with abrupt transition to rims with markedly lower S-content. S-rich apatite cores from Yerington have SO_3 ranges similar to apatites from anhydrite ($CaSO_4$)-saturated magmas such as El Chichón and Pinatubo, crystallized early (< 15% xls), and likely predate to coincide with initial $CaSO_4$-saturation. Low-SO_3 apatites or apatite rims record the reduced SO_3-carrying capacity of the melt at lower temperature and higher silica, and imply that $CaSO_4$ was crystallizing. Low Cl (≤ 0.08 wt.%) and decoupling of Cl from SO_3 (low Cl-high SO_3) in apatites from granites evolving ore fluids suggest aqueous fluid saturation and that SO_3 solubility in these fluids was small. Successive extractions of magmatic aqueous fluids may have completely dissolved all anhydrite crystals and provided batches of oxidized sulfur to fluids.

TWO STAGES OF SEPARATION ORE-FORMING MEDIUM

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Investigations inclusions in minerals give evidence that besides glass and fluid inclusions exist yet one type - melt-brine inclusions. For these type are typical: high concentration of fluids and ore-forming elements (up to thousand times higher than in acid melt), separation from melt by temperatures higher than liquidus and stability in changing PT conditions. When melt-brine(s) meet underground waters, and dilute by them, it precipitates most part of ore and turns into classical hydrothermal solution with low ore elements concentration. Melt-brine forms by separation initial acid magma into: secondary acid magma and melt-brine. This process was confirmed by laboratory experiments. So, in the nature exist two types of hydrothermal solutions: 1. classical hydrothermal solutions generated at the final stage of acid magma differenciation; these solutions can't create industrial ore deposits and 2. result of melt-brine dilution; precipitation ore from them take place in the process of dilution.

SE31 Mechanics and thermalfluid-dynamics of volcanic processes: modelling, observations and laboratory experiments (co-sponsored by NP)

Convener: de Natale, G.
Co-Conveners: Allard, P.; Bonafede, M.

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TRANSFER STRUCTURES AND VOLCANIC ACTIVITY ALONG THE TYRRHENIAN MARGIN OF CENTRAL ITALY

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The Tyrrhenian margin of the central italian peninsula has been characterized by Plio-Quaternary extension, mainly occurred through NW-SE normal faults, offset by coeval NE-SW normal and oblique transfer faults. A sequence of Plio-Quaternary volcanoes developed along the margin, in correspondence with NE-SW structures, suggesting a systematic relationship. The largest central volcanoes, often showing caldera-like depressions, are related to wide-spaced NE-SW faults. At the intersection among NW-SE and wide-spaced NE-SW systems, extensional stresses focus, thinning the crust and enhancing the rise of magma. Conversely, smaller districts (Amiata, Tolfa, Ceriti, Ernici) only display fissural eruptions, connected to narrow-spaced NE-SW transfer systems. In order to study the relationship between narrow-spaced transfer systems and fissural volcanism, analogue and numerical modelling have been performed. Analogue sand-box models in extensional domains simulated the development of vertical transfer faults linking offset normal faults dipping 60°. Analogue models confirm that NE-SW systems may represent transfer faults of NW-SE normal faults. The mechanical model shows that, due to the least lithostatic load, vertical faults such as transfer faults, need the smallest magmatic pressures to be penetrated. Vertical faults can moreover be penetrated at greater depths, tapping the potentially more primitive magma. The models suggest that the location and the structural setting of volcanoes on the Tyrrhenian margin are related to the presence, spacing and vertical geometry of NE-SW transfer systems.

TEMPORAL VARIATIONS IN GROUNDWATERS RADON CONTENT AND GEOPHYSICAL ACTIVITY IN CAMPI FLEGREI (SOUTHERN ITALY)

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The Campi Flegrei caldera is an active volcanic complex, located west of Naples, presently exhibiting slow vertical ground movements known as "bradyseism". Two uplift phases, each of 1.8 m, affected the area respectively in 1970-1972 and 1982-1984; both were followed by slow subsidence.
Vertical ground movements are accompanied by horizontal displacements, gravity changes, enhanced seismic activity during the strong uplifts and by variations of geochemical parameters in groundwaters, fumaroles and soil atmospheres.
The present paper takes into account the time series of radon (Rn) content, pH and temperature in groundwaters, ground deformations and gravity changes covering the 1982-1997 period. It is particularly focused on the analysis and interpretation of data covering the subsidence phase (1985-1997) following the crisis. Some almost contemporaneous variations and other interesting signatures have been observed in both the geophysical and geochemical behaviours. The relationships between groundwater features and geophysical activity have been ascertained in order to define common sources and mechanisms.

SPACE-TIME PATTERNS OF SEISMICITY AND STRESS-STRAIN PARAMETERS AT MT. ETNA, SICILY: VOLCANIC AND TECTONIC IMPLICATIONS

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The local shear-earthquakes recorded at Mount Etna between 1990 and 1996 have been analyzed for hypocenter locations and fault-plane solutions. Related stress and strain parameters were then computed by the Gephart-Forsyth and Kostrov algorithms, respectively. Space-time patterns of seismicity, seismogenic stress and seismic strain over the whole period investigated (which includes two notable eruptive phases in 1991-93 and 1995-96) have been analyzed jointly with ground deformation, gravimetric, and geologic information available. The findings lead us to believe that seismicity located in the upper crust beneath the volcano is mostly associated with east-west magma hydraulic pumping in ca. north-south-oriented uprise structures, and closely relates to inflation phases of the volcano preceding eruptive episodes. It is nothewörty that volcano deflation revealed by geodimetric and tilt data during the 1991-1993 major eruption was not accompanied by any significant shear-type shallow earthquake. In the intermediate and lower crust (10-30 Km) beneath the volcano, the regional-scale tectonic compression, related to the Africa-Europe north-south slow convergence, appears to be dominant in terms of stress-strain effects. Finally, some analogies between the results of the present study and the findings of similar investigations performed in other areas are discussed.

MODELLING GRAVITY VARIATIONS CONSISTENT WITH GROUND DEFORMATION IN THE CAMPI FLEGREI CALDERA (ITALY)

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The last two episodes at Campi Flegrei (1970-72 and 1982-84), both characterized by significant ground uplift and gravity variations, are studied employing an elastic model with a spherical source of deformation applied to a stratified half-space. The contributions to gravity variations produced by the displacements of the surface, the subsurface layers, the relative volume change and the deformation source at four different stations (Serapeo, Solfatara, Bagnoli and La Pietra) were computed. These contributions and the measured (at the same stations) gravity residuals were compared, to draw inferences on the physical processes responsible for the deformation. Results show that an inflation at constant mass would produce gravity residuals much lower than observed, so that this deformation mechanism can be safely ruled out. An inflation source at constant density would predict gravity residuals compatible with observations, even if the resolving power of gravity data prevents accurate assessment of the density of the emplaced material. If the geothermal system is assumed to be responsible of the observed anomalies, computed residuals become compatible with measured values, due to the input of new fluid mass. The comparison between two stratified models reveals that gravity anomalies are not significantly sensitive to the detailed knowledge of the density stratification.

THERMO-VISCOELASTIC MODELS OF THE DEFORMATIONS AND GRAVITY CHANGES DUE TO THE MAGMATIC BODIES OF PRISMATIC SHAPE

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The paper presents theoretical formulae for the calculation of the stress and strain tensor components due to a source of heat of prismatic shape embedded in the viscoelastic halfspace (lithosphere) of the Kelvin type. The formulae for the gravity perturbation due to the volume dilatation connected with thermo-viscoelastic deformations is derived as well. Numerical results are presented in the graphs which show gradual approaching stress and strain to the steady state. The surface thermo-viscoelastic stresses are mainly of tensile type. Their values are well comparable with critical stresses required to cause creep or fractures of the surface. The displacement of the epicentral region causes a pronounced dome.

THEORY AND EXPERIMENTS RELATED TO THE SPREADING OF SOLIDIFYING MELTS

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The plane spreading of a viscous melt on a horizontal plate, driven by gravitational forces, for isothermal conditions already represents a problem with a free liquid/gas interface. This problem has been treated in literature both theoretically and experimentally. If the plate is kept at a temperature below the solidification temperature of the melt, we expect solidification of the melt in the proximity of the plate and, thus, a second free interface (solid/liquid) will be present in the problem.
Firstly, we discuss a set of experiments conducted with both high and low Prandtl number melts, namely Canauba wax and a low-melting metallic alloy.
Secondly, we develop models for the theoretical treatment of solidifying spreading flows for the limiting case of large Peclet numbers.
Thirdly, a carefull comparison of the experimental observations and the theoretical results is conducted.

USE OF EARTHQUAKES AND DEFORMATIONS AS REMOTE STRESS-METERS

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We investigate the relationship between intrusive events, ground deformation, and seismicity at Kilauea, Hawaii. The beginning of the 1983 Kilauea eruption was associated with a 2.1 meter fissure opening in the east rift-zone and a significant spatially-varying change of the south-flank seismicity. A general constitutive formulation [*Dieterich*, 1994] for earthquake occurrence is employed to invert changes of earthquake rates for Coulomb stress changes. An independent determination of the coulomb stress changes is obtained by a 3D boundary element modeling of the ground surface deformations. In this model, magma is emplaced in a dike-like vertical reservoir coupled with a freely sliding low-angle thrust fault. We find that the Coulomb stresses determined from seismicity correlate with an eruption process where a vertical dike propagated to the ground surface. A dike overpressure of 3MPa is determined for the eruption. The comparison between stresses determined by these two methods also helps defining the geometry of the south flank. This study demonstrates that the earthquake rates can be used quantitatively to determine stress changes associated to volcanic or seismic events. It also shows that the two types of inversion can be used complementarily to determine the stress sources: seismicity brings an information from the inside of the study volume whereas deformations give a precise information at the surface.

CRUSTAL STRUCTURE AND UNREST EPISODES AT THE ALBAN HILLS VOLCANO, CENTRAL ITALY

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The Alban Hills, a Quaternary volcano lying 20 km SE of Rome, last erupted 19 ka and has produced about 290 km^3 of eruptive deposits since 580 ka. Modern observations show that intermittent swarm activity originates primarily beneath the youngest phreatomagmatic craters. Results from seismic tomography allow identification of a low-velocity region, perhaps still hot or partially molten, more than 6 km beneath the youngest craters and a high-velocity region, probably a solidified magma body, beneath the older central volcanic construct. Thirty centimeters of uplift measured by releveling supports the contention that high levels of seismicity during the 1980s and 1990s resulted from accumulation of magma beneath these craters. The volume of magma accumulation and the location and amount of maximum uplift was probably at least 40×10^6 m^3 and 40 cm. Older levelings completed in 1891 and 1927 suggest earlier episodes of uplift. The magma chamber beneath the western Alban Hills is probably responsible for much of the last 200 ka of activity, is still receiving intermittent batches of magma, and is, therefore, continuing to generate modest levels of volcanic unrest. Bending of overburden is the most likely cause of seismicity, which have hypocenters above the 6-km-deep top of the magma reservoir. In this view, the most recent uplift and seismicity are probably characteristic and not precursors of more intense activity.

LARGE SCALE RESISTIVITY IMAGING AT MERAPI VOLCANO

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Resistivity of geological structures is mainly controlled by their porosity, the resistivity of the fluids contained in them, and temperature. Highly porous rocks, extremely dry or saturated with ionic hydrothermal fluids, high temperature contrasts as well as good conductivity of alteration minerals make resistivity an extraordinarily informative quantity for structural investigation of active volcanoes. However, poorly accessible terrain and poor grounding conditions complicate the application of conventional resistivity technology on volcanoes and require a special design of field equipment, data enhancement, modelling, and inversion strategies. The paper presents the results and the technology of a dipole-dipole resistivity survey of nearly 3 km length and a depth of investigation of more than 800 m, set out radially along the west flank of Merapi volcano, Indonesia, between 1300 m and 2000 m above sea level. The resulting pseudosection shows a 2D vertical slice through the resistivity distribution reaching through a high-resistivity layer of unsaturated pyroclastica (rho > 1000 ohmm) into an extremely low-resistivity, presumably hydrothermal, zone (rho < 50 ohmm). The combination of a robust, portable, light-weight DC-transmitter especially designed for poorly accessible volcanic terrain and 24-bit data receiver technology (RefTek) represent an efficient method of data acquisition. Selective signal stacking and other signal enhancement procedures allow higher spatial resolution and greater depths of investigation. Cross-flank volcano resistivity monitoring will be discussed.

AN EMPIRICAL GREEN FUNCTION APPROACH TO STUDY THE RUPTURE OF FLUID-INDUCED MICRO-EARTHQUAKES

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The inversion method finds the best rupture model to explain directivity effects in P- and S-phases. We approximate the integral in the moment tensor representation using a sum over spatial and temporal centroids radiating at times calculated from the rupture models tested. The about 40 centroids used restrict the method to wavelengths larger that 1/6 of the maximal dimension of the fault plane. To ensure an overdetermined inversion problem and a good resolution we estimate only five source parameters; 2 fault dimensions, rupture duration, source strength and rupture direction. Two models are tested; uniform rupture on an elliptical fault and unidirectional rupture on a rectangular fault. Tension as well as shear faults can be handled. Additional to the separation between both models we distinguish between rupture and auxiliary plane. We use the seismograms of an observed small event with similar source mechanism as the studied event as empirical Green functions. Thus sensor site effects and sensor characteristics are unimportant.
We test the method on synthetic waveforms and on hydraulic induced microcracks in salt recorded with 8 piezo sensors. The physical mechanisms leading to induced seismicity during hydraulic fracture experiments are expected to be similar to the ones during magma-dike injections in volcanic areas. The preliminary results indicate, besides the small extension of the cracks $(20-40mm)$, that the rupture velocity is small compared to pure tectonic earthquakes.

A MECHANICAL-THERMALFLUID-DYNAMICAL MODEL FOR CAMPI FLEGREI UNREST EPISODES: POSSIBLE EVOLUTION TOWARDS CRITICAL PHENOMENA.

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We develop a model for describing water flow in a porous medium under the effect of thermal and pressure gradients. The model simulates geothermal systems in calderas. Given the boundary conditions and the fluidodynamical properties of the medium, the model allows to compute, in stationary states, parameters characterising the flow, i.e., flow velocity, temperature and pressure distributions at depth, etc. The model is applied to investigate the effects of the local geothermal system on the unrest episodes at Campi Flegrei caldera. Using experimentally determined fluidodynamic parameters for the caldera rocks, it is shown that changes of water flow in shallow aquifers, under the effect of a pressure and/or temperature variations within of geothermal system can be very important in the genesis and evolution of unrest crises. In particular, they can strongly amplify the effect of pressure increase in the magma chamber on ground uplift. They can also explain the time scales of evolution of ground movements, in terms of transit times of the water front and of the connected temperature fronts due to advective transport . The validity of the approximations used in the monodimensional model, as well as the main evidences for dominant convective transport are discussed. On such grounds an integrated mechanic-thermalfluid-dynamical model is built, explaining the Campi Flegrei unrests.

THE BROADVES SEISMIC EXPERIMENT: FIRST RESULTS ON THE LITHOSPHERIC STRUCTURE BENEATH THE CAMPANIAN REGION AROUND THE VESUVIUS VOLCANO

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During the summers of 1996 and 1997 two temporary arrays of broad band seismic stations were installed in the Campanian region around the Vesuvius volcano. The aims of this experiment (BROADVES) are to study the structure beneath this sector of the Southern Italy, and to analyse, for the first time using broad band instruments, local seismicity. The results of this experiment should give unique informations about the substructure of the Campanian volcanoes and, more specifically, about the mechanisms of local seismicity at Vesuvius, discriminating between volcano-tectonic earthquakes and low frequency, fluid-induced events. Each array was composed by 7 continuously recording Reftek digital seismic stations, equipped with 3 component broad band sensors (CMG-40T: 20 s; CMG-3T: 100 s or 360 s).We present the results of a teleseismic tomographic inversion for the P-wave velocity structure beneath the volcanic area and the surrounding Apenninic chain, carried out merging the data collected from the broad band arrays with the data recorded by the Italian Seismic Network. Furthemore, we present some preliminary results on the Moho geometry derived by the application of the receiver function technique.

A NEW TYPE OF SULPHIDE ORE DEPOSIT IN THE FIELD OF IGMIMBRITE VOLGAMIG ACTIVITY ABOVE THE SUBDUCTION SOME

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It is well known, that in the ignimbrite volcanic activity fields the Kuroko type sulphide deposits are manifested. The latter are developed in extentional regime in island arcs above subduction zones .The deposits occur within collapsed submmarine calderas, after completing of the cycle of the ignimbrite activity, and are related to postcollapse extrusions of the ryolitic domes. In the Lesser Caucasus, in the Bolnisi ore disrict in the Upper cretaceous ignimbrite fields, within collapsed calderas two signif Icant nonferrous and copper-pyrite deposits occur. The geological and geo-chronological investigations let us as same, that these deposits could not belong to Kuroko type, because ore generation processes procureded before the ignimbrite ejection and before caldera collapse. The origin of these ore bodies took plase during the tumicsent stage, when the felsic magma intruded and formed magmatic chambers,that conditioned succeeding ignimbrite activity. These intrusives were the source of ore solutions for the deposits. W, E. Elstone (1992) and I.Rytila(1992) described tumiscent ore manifestation outside the caldera borders. The Madneuli and Tsiteli Sopeli deposits represent the only tumiscent economically sigTilficant deposits described within caldera structures. Thus, we propose to distingwish such type of deposit as Bolnisi type deposit.

EFFECTS OF STRESS FIELDS ON THE INTRUSION AND EXTRUSION FREQUENCIES OF CENTRAL VOLCANOES

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In rift-zone central volcanoes in Iceland, eruptions are frequent (typically one every several hundred years), of small volume (normally less than 0.1 km^3) and mainly fed by thin (average thickness 0.5 m) inclined sheets. In the rift zone outside central volcanoes, eruptions are rare (typically one every several thousand years) but of large volume (typically more than 1 km^3) and mainly fed by thick (average thickness 4-5 m) subvertical dykes. Boundary-element studies of magma chambers indicate that these empirical relations, as well as the formation of specific central volcanoes in the rift zone, can be explained by the stress fields around the chambers. Tensile stress concentration around the shallow source chamber of a central volcano leads to the segment containing the chamber rupturing, and the central volcano erupting, much more frequently, but with smaller intrusive and extrusive volumes, than the surrounding parts of the rift zone.

SLOW ROCK FRACTURE AS AN ERUPTION PRECURSOR AT SOUFRIERE HILLS VOLCANO, MONTSERRAT

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The onset of magmatic activity at Soufriere Hills volcano, Montserrat, was preceded by a tenfold increase in rates of seismic event. A new model of subcritical rock failure shows that the increase is consistent with the episodic growth of the feeding conduit at a rate controlled by progressive rock weakening. The preferred weakening mechanism is stress corrosion, for which circulating fluids chemically attack the country rock and promote failure at stresses smaller than the rock's notional bulk strength. Episodic failure may result from heterogeneities in bulk rock resistance or from variations in effective resistance due to the formation and failure of a damage zone ahead of the main feeder. Combined with traditional seismic monitoring techniques, the results highlight the potential of slow-cracking models for improving eruption forecasts.

PHYSICAL SOURCE MODELS FOR HARMONIC TREMOR

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For over 18 hours, the tremor at Lascar volcano, Chile, was characterized by a harmonic spectrum with narrow peaks at a fundamental freqency of about 0.63 Hz and up to 30 overtones at exact integer multiples. Fluid dynamics offers at least three physical source models for this harmonic tremor, which produce repetitive, nonsinusoidal waveforms: The release of gas through a very small outlet (the soda bottle model), slug flow in a narrow conduit, and eddy shedding at obstacles or corners. These models represent different flow regimes, each with its own characteristic range of Reynolds numbers. For each model the fundamental frequency of the tremor is related to the Reynolds number for the flow. Combining the Reynolds numbers for each model with typical kinematic viscosities for the possible volcanic fluids -- magma, water, steam, air or some combination, at appropriate temperatures and pressures -- provides limits on such physical parameters of the volcano as the dimensions of the flow conduit and the flow velocity of the fluid generating the tremor. All three models imply that the tremor is generated by the movement of steam or water near the surface.

NUMERICAL MODELING OF MAGMA WITHDRAWAL FROM COMPOSITIONALLY STRATIFIED MAGMA CHAMBERS

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Magma withdrawal from a compositionally stratified magma chamber is investigated using a physical model based on the mass, momentum, enthalpy and composition equations for an incompressible fluid with newtonian rheology. Magma viscosity and density are functions of temperature, composition and crystal content and are computed using the program MELTS (Ghiorso et al., 1994). The small density variations are accounted for through the Boussinesq approximation. Equations are solved in a two-dimensional domain adopting the Finite Element Method. The chamber is initially filled of two layers of magma with different composition and temperature. During the eruption, new magma enters from an inlet at the bottom of the chamber, while the resident magma is allowed to exit through a conduit located at the top. Different inlet geometries and mass flow rates are investigated in order to study magma mixing and the temporal variation of the composition of the erupted products. The chamber dimensions and the physical properties of the magma are prescribed similar to the pre-eruptive conditions of the 79 AD Vesuvius eruption.

MAYON VOLCANO; PHILIPPINES: MODELIZATION OF STRESS BALANCE

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Mayon volcano is part of the Bicol Volcanic Chain, a peninsula in the southeast of Luzon island. The eruptive history during this century shows a nearly periodic behaviour: The volcano erupted almost every ten years.
During the last two eruptions indications for tidal triggering of activities were found. The pressure increase in the vent due to vesiculation was modelled assuming a temperature decrease of 2°C per year. The results were compared with the stress provided by the tidal forces (body tides and ocean tidal loading). It turns out that during a period of several days the small tidal forces may affect the stress balance considerably if the volcano is already in a critical state.

Comparative study of pyroclastic deposits in Campi Flegrei (Southern Italy): evidences of recurrent eruptive and depositional mechanisms.

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The intra-calderic explosive activity of Campi Flegrei produced tens of mono-genetic volcanoes. A comparative analysis of the most representative deposits suggests that the eruptive and depositional conditions of the different deposits were recurrent. Several evidences indicate a common explosive magmatic background of most deposits types modulated by different degree of interation with shallow water in determined the style of eruption. The abundance of fresh, completely vesiculated fragments also in phreatomagmatic deposits as well as the presence of different order of vesicles and coalescence indicate that the fragmentation took place only in the very final stage of magma ascent and vesiculation. The relations between vesicle walls and broken surface of the clasts suggest that magmatic and hydromagmatic fragmentation both occurred after a near complete magma vesiculation. According to these evidences and considerations a general two stage model of the intracalderic, explosive activity forming the monogenetic volcanoes in Campi Flegrei consists of : a) rapid magma rise for high bubble growth rate at low confinig pressure in a shallow magma reservoir; b) continuous or pulsating magma water interaction possibly due to local decompression or coduit instabilities that allowed and avoided access of water to the conduit.

MULTIPHASE FLOW MODELING AND SIMULATION OF EXPLOSIVE VOLCANIC PROCESSES

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Almost 15 years ago, the recognition of the multiphase nature of many eruptive processes opened a new research field in volcanology. This approach is based on the extension of the fundamental Navier-Stokes continuum mechanics equations to a multiphase and multicomponent mixture. According to this theory, different phases are treated as interpenetrating continua and the mass, momentum, and energy interphase transport terms are explicitly accounted for in the conservation equations. Constitutive equations of the dispersed particulate phases can be based on semi-empirical correlations calibrated by lab experiments as well as on the recently invented concept of granular temperature deriving from the extension of the dense phase kinetic theory of gases to particulate flows. Such a new variable allows the description of critical flow properties, such as solids pressure and viscosity, in terms of first principles. Different types of explosive volcanic events, such as collapsing columns, pyroclastic flows, dome and phreatic explosions have been simulated by multidimensional physical models based on the presented multiphase flow theories. Results highlight relevant mechanical and thermal non-equilibrium effects between the different phases of the mixture that can affect the large-scale dynamics of the explosive process.

COSEISMIC DISPLACEMENTS AND CREEPING ALONG THE PERNICANA FAULT (ETNA, ITALY) IN THE LAST SEVENTEEN YEARS: A DETAILED STUDY OF A TECTONIC STRUCTURE ON A VOLCANO

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The Pernicana fault is a well evident tectonic fault located on Mt. Etna (Sicily). Movements across this structure have been monitored, in the last seventeen years, by a levelling network owned by Osservatorio Vesuviano. During the monitoring period, the network has recorded coseismic displacements associated to earthquakes of magnitude 4 to 5, as well as displacements not related to earthquakes. We present a detailed study of the displacement data, aimed to model the geometry and mechanism of this fault, as well as the size and mechanisms of individual earthquakes. The total recorded displacements during the last seventeen years are well interpreted by a single, homogeneous rectangular normal fault, with dislocation and size corresponding to a magnitude 5.7 earthquake, thus revealing an intense dynamics along such a fault. The heterogeneous slip distribution associated to the two largest earthquakes has been also inferred from coseismic displacement data. Seismic moments of such earthquakes turn out to be considerable higher than reported in seismic bulletins (about 1 degree of magnitude). The results obtained here evidence the high potential of levelling data in the detailed study of a rather peculiar kind of tectonic structure on a volcano.

NUMERICAL MODELING OF MAGMA ASCENT ALONG VOLCANIC CONDUITS

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The steady, one-dimensional, multiphase non-equilibrium ascent of magma along the volcanic conduit during explosive eruptions is numerically simulated by thermofluid dynamic modeling. The relevant magma properties (gas solubility, density, viscosity) are allowed to change along the conduit due to mass transfer between the phases, and are calculated on the basis of the chamical composition of magma in terms of ten major oxides plus dissolved volatiles and of an equation of state for the real behavior of the gas phase. The model accounts for the presence of water and carbon dioxide exsolving from the liquid, and is based on the coupling between fluid dynamics and the most advanced models for the magma properties. Magma fragmentation is assumed to occur at either a critical value of the gas volume fraction, or at a level in the conduit where the elongational strain rate overcomes the critical strain rate imposed by the magma structural relaxation time. The model reveals many features of the magma ascent dynamics in explosive eruptions, and can be used to investigate the role of the different parameters involved in the ascent process, or to forecast the volcanic hazard by defining the conduit exit conditions for a given set of initial (magma chamber) conditions.

PRELIMINARY RESULTS FROM A BROADBAND SEISMIC EXPERIMENT AT STROMBOLI VOLCANO, ITALY.

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During September-October 1997 a joint Italy-US team conducted a large-scale broadband seismic experiment to investigate the long-period signals associated with the ongoing explosive activity at Stromboli volcano, Italy. 21 three-component, 60-s Guralp CMG-40T sensors were deployed in three circular patterns surrounding the active craters at altitudes of about 100, 500 and 750 m. During four separate days of data acquisition, we recorded continuosly 7 to 24-hour-long intervals of volcanic signals, thus obtaining the most detailed broad-band data set ever collected on an active volcano. Preliminary results from analyses of selected waveforms in the 2-50 s period range show the existence of at least two distinct sources repetitively acting in time. Polarization vectors inversion clearly indicate that both sources are constrained within a shallow volume located N-NW beneath the active vents. Ground motion observed prior and during the summit explosions is consistent with an inflation followed by a rapid deflation of the shallow plumbing system. Future goals to be attained include Green's functions calculation using a 3-D finite difference approach and inversion of waveforms for moment tensor analysis.

VISCOUS FLOW IN A CHANNEL: APPLICATION TO LAVA FLOWS

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We propose a 3D model describing a channeled lava flow in the proximity of the eruption vent. We describe the lava as an isothermal Newtonian liquid flowing in a rectangular channel down a constant slope. The flow velocity is calculated by an analytical steady-state solution of the Navier-Stokes equation. The surface velocity and the flow rate are calculated as a functions of the flow thickness for different flow widths and the results are compared with those of a 2D model: it appears, for a typical Etna's lava flow, that the influence of the levees on the flow dynamics is not negligible when the flow width is less than 25 meters. The model predicts the volume flow rate corresponding to the surface velocity taking into account that both depend on the flow thickness. We propose a model for the evaluation of the effusion rate by knowing the lava flow width, the slope of the topography, the lava density, the surface flow velocity and either the lava viscosity or the flow thickness.

Seismic activity at the Solfatara crater (Campi Flegrei caldera) shows different sources mixing of fumarolic fluids and possible parameters to forecast the occurrence of new earthquakes.

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Here we describe temporal variations of noble gas and carbon isotopes and chemical data of fluids collected from 1990 to 1994 at the Bocca Grande fumarole (Solfatara crater), before the occurrence of a seismic swarm. After more than seven years of quiescence: a sudden vertical ground deformation and a seismic swarm of 100 quakes with a Mmax=1.5 with epicenter located beneath the Solfatara crater, were recorded from August 23 to 25 1994. Isotopic composition of He, Ne, Ar and C (from CO2) and chemical composition of He, Ne, Ar, H2, CH4 and N2 have been analysed from fumarolic fluids. To date these isotopic ratios have not been used as precursors of earthquakes, although several cases have been reported in which helium isotopic ratio was used to interpret volcanic unrest. All the analysed isotopic ratios, chemical species and a calculated equilibrium temperature show a significant change a few months before the occurrence of the seismic activity and ground deformation, followed by a sudden return to values recorded prior the swarm. Migration towards the surface of deep (and hotter) gas phase related to crustal and magmatic sources with the following decrease of the surficial atmospheric component is the cause of such wide variations.

A NEW PRESSURE VESSEL FOR MAGMA- AND ROCK-H2O INTERACTION STUDIES

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A already recognized on volcanoes, water under pressure coming in contact with magma bodies or hot rocks may interact explosively originating phreatomagmatic or phreatic eruptions if some boundary conditions between the two media are present. Because of experimental difficulties, preceeding studies have been mainly directed to reproduce the natural processes and products using artificial analogues without much reference to P,T,Xi, and gases real conditions. Therefore it has been designed and realized an experimental apparatus able to perform interaction experimentsup to Pmax of 200 Mpa and Tmax of 1200C using natural rocksof known compositions. The interaction cell is contained within a two liters IHPV (internally heated pressure vessel) and is equipped with a membrane allwing volume variations due to H2O liquid-vapor transition. The sample, in form of a rock cylinder 20x60mm, is confined by a Pt crucible inside the cell and injected via a Pt capillary tube of H2O with known quantity and pressure. The pressure differenzial between the inside and the outside of the cell can be also controlled:i.e. lowering of the cell outside pressure can trigger the explosive magma-water interaction. Experiments are in progress on magma-H2O interaction processes at Vulcano Is. And on liquid-vapor H2O transition controlling bradisisma in Campi Flegrei area.

STRESS CHANGES ASSOCIATED WITH VOLCANIC SOURCES: AN EXAMPLE FROM KILAUEA RIFT ERUPTIONS.

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The dynamics of volcanic sources involves high strain and stress changes in the host rocks. Strong perturbations to the local stress regime are then produced, which can attain much larger values than the regional stress field. Modeling of such perturbations can be hence of fundamental importance to interpret the evolution of volcanic unrests and, in particular, the seismicity generated during unrest episodes. In this work, an analytical method, based on the formulas by Okada (1992) is developed to simulate strain and stress changes associated to dynamics of volcanic sources such as: magma chamber overpressure, dike and rift opening. Magma chamber overpressure is simulated by isotropic point sources, dike and rift opening is simulated by rectangular, finite faults with dislocation normal to the fault plane. In order to study the influence of volcanic sources on the earthquake generation, Coulomb stress changes are computed for several sources of different depth and geometry. Such changes can be computed both on fixed fault plane orientation and on the optimally oriented planes, defined as the planes with maximum total Coulomb stress, regional plus local. The obtained results give insight on the expected locations and mechanisms of seismicity associated to volcanic sources. An example of application of the method to the study of the seismicity of the South flank of Kilauea is presented. Results show that such seismicity, and the seaward movement of the southern flank, can be interpreted in terms of stress changes associated with northeastern rift intrusions and eruptions.

SE32 Crustal melting in nature and experiment

Convener: Kotkova, J.
Co-Convener: Patino-Douce, A.

CRUSTAL MELTING IN NATURE: PROSECUTING SOURCE PROCESSES

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Commonly, there is a spatial and temporal association of granite with crustal-scale shear zone systems — small batches of magma occur as meter-scale sheets in stromatic migmatites in zones of higher strain, inhomogeneous migmatites occur in zones of lower strain, with vertically-sheeted kilometer-scale ellipsoidal plutons, and large tabular plutons (10^3 km^3) are discordant to structures. Melt extraction and transport is a batch process and plutons form by aggregation of multiple melt batches: we may expect similar crystallization ages, but dissimilar batch-specific isotopic compositions. For example, within part of the Central Maine Belt, N Appalachians, precise U-Pb zircon/monazite crystallization ages of sheets, schlieric granite within migmatites and kilometric plutons are in the range *c.* 410-404 Ma, within 2 Ma at 95% confidence limits. In one pluton, synchronous ages for grey granite and leucogranite suggest melt extraction and transport are fast processes. Leucogranite textures and covariation in K, Rb, Sr and Ba distributions are incompatible with FC, but consistent with volatile phase-absent Ms-dehydration melting. This pluton shows heterogeneity in Nd isotope compositions (grey granite ε_{Nd} (404 Ma) of + 0.1 - -1.8; leucogranite ε_{Nd} (404 Ma) of -5.3 - -8.0), which we interpret to reflect derivation from two sources, to preserve within-source heterogeneity and to imply efficient transport. In spatially restricted segments of orogenic belts, regionally-significant crustal melting in nature occurs at fast rates within short timescales (~10^7a).

GENERATION OF LEUCOGRANITES IN THE KERALA KHONDALITE BELT, SOUTHERN INDIA

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Gneisses of pelitic and psammitic composition form a major crustal component of the Kerala Khondalite Belt (KKB) in southern India and were subjected to biotite dehydration-melting at different stages of the tectonometamorphic evolution of the KKB during Pan-African orogeny. Metapelites were migmatised prior to and simultaneously with the ductile deformation of the gneisses. The degree of melting was high and melt segregation was very effective leaving behind a mafic granulitic residue of garnet, cordierite, sillimanite ± biotite, K-feldspar and graphite. Contrasting to this, partial anatexis of psammitic gneisses took place under static conditions and the degree of melting did not exceed 5 - 10 % which led to the generation of a ăresiduumô consisting of isolated garnet-bearing in-situ leucosomes which occur homogeneously distributed in a quartzofeldspathic biotite gneiss matrix. The generated melts are leucogranitic and peraluminous in composition and intruded the gneisses subparallel and discordant to their foliation. Field observations and the mineralogy of the granites, particularly the occurrence of Al2SiO5 polymorphs, yield important information on the P-T-conditions of melt generation and crystallization and will be discussed.

LIMITATIONS IN APPLYING EQUILIBRIUM STUDIES TO OPEN PLUTONS IN CRUSTAL GRADIENTS

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Equilibrium studies of minerals and fluids necessarily are on closed systems that lack gradients. They best describe local phase events in restricted volumes of the crust, such as liquefaction, partial or total, which generates silicate liquids, magma. However, large plutons are open chemically, and subject to gradients in T, P and composition. Plutons move physically as diapirs and chemically by disequilibrium dissolution-crystallization reactions along gradients in the earth's gravitational field, by cycling energies of liquefaction. Plutons are silicate solutions that are governed by principles of solution chemistry: solubilities, chemical potentials, and kinetics of irreversible reactions.

TWO STAGE MELTING AROUND MAFIC RESERVOIRS: AN EVIDENCE FROM THE PROTEROZOIC OF BOHEMIAN MASSIF

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Two stage melting and extensive interaction between mafic magmas and high-temperature contact metasemipelites (max. 830°C) were studied around a small gabbro - quartz diorite intrusion in the Proterozoic sedimentary fundament in the western part of the Bohemian Massif (Czech Republic). The intrusion of dry gabbronorite magmas caused dehydration melting of surrounding semipelites in the first stage producing relatively hot, vapour-undersatured leucogranitic magma (with refractory garnet) which segregated and formed dykes of granophyres or pegmatites and stocks of microgranites. The interaction of gabbroic magma with anatectic material generated biotite-amphibole quartz diorites by approximate reaction: 70-75 % gabbroic magma + 14-25 % semipelite + 3-12 % anatectic granitic melt giving 65-90 % quartz diorite melts + 7-25 % plagioclase + 2-10 % olivine + accessory clinopyroxene (fractionating mineral assemblage in cumulates). The fluid release during quartz diorite crystallization enhanced the second stage of semipelite melting which caused vapour-present formation of contact metatexites to diatexites of biotite tonalitic composition (partly with residual cordierite) preserving anatectic textures and various crystallization microstructures. Diatexites represent low-temperature vapour-saturated magmas with very restricted ability of segregation and movement containing admixture of solid material (xenoliths, restites, plagioclase phenocrysts).

FORMATION AND EVOLUTION OF HP LEUCOGRANULITES: EXPERIMENTAL CONSTRAINTS AND UNRESOLVED ISSUES

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High-pressure (HP) leucogranulites of the Bohemian Massif are interpreted as the metamorphosed equivalents of HP leucogranites produced by deep crustal melting. This is supported by their preserved mineral assemblages (Grt-Ky-Kfs), bulk rock chemistry, P-T estimates, and garnet and accessory phases trace element abundances. Following melting and peak metamorphism, the leucogranulites have been exhumed from lower crustal depths to their present position at the highest structural level of the Gf÷hl Nappe. The near-ITD decompression P-T path and geochronological data imply high exhumation rates. The dry character of the leucogranulites reflects the water-undersaturated conditions that prevailed during formation of leucogranites and their subsequent recrystallization in the middle and lower crust. In the Qz-Ab-Or ternary diagram compositions of the leucogranulites are displaced towards the Qz-Or join, which corresponds to experimental results for water-undersaturated melting. Trace element (mainly REE) abundances in whole rock, garnet and accessory phases are consistent with Ms-Bt dehydration melting coupled with Kfs fractionation. The melting reactions potentially involved in generation of HP leucogranite melts, protoliths and mechanisms of magma ascent to higher crustal levels will be discussed, using experimental data for water-saturated and dry melting.

TWO-STAGE SYN-EXTENSION LEUCOGRANITIC MAGMATISM IN THE TORMES GNEISS DOME, NW IBERIAN MASSIF, SPAIN

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The Tormes Gneiss Dome (TGD) is a high-grade metamorphic complex affected by a major episode of extensional deformation (D2). The complex was intruded by two types of syn-D2 granitoids: (1) garnet-bearing and (2) cordierite-bearing, peraluminous leucogranitoids with abundant metapelitic enclaves, which are mainly concentrated in the Lower Unit located in the core of structural dome. The P-T vectors deduced from thermobarometric calculations in metapelites, the sequence deduced from melting reactions and the existence of two generations of mineralogically and structurally different leucosome segregations, suggests that the migmatization in the Lower Unit ocurred in two main pulses as consequence of exhumation and near isothermal decompression. Leucogranites with garnet are interpreted to have formed close to the thermal peak, whereas leucogranites with cordierite are interpreted to have formed during the decompression stage.

Melting during post-thickening uplift: Mamil Choique Granitoids of the North Patagonian Massif

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Epidote bearing Mamil Choique Granitoids (MCG) made up the most extensive outcrops of the Paleozoic basement of the North Patagonian Massif and are the product of melting as a consequence of post-thickening uplit. Emplacement slightly postdate peak metamorphic conditions as shown by overprinting relation of Ms porphyroblasts overgrowing medium grade parageneses of their metasedimentary country rocks. Crystallization ages are pooorly defined but in any case low $^{87}Sr/^{86}Sri$ is characteristic.

Three deformational phases has been recognized in MCG and its country rocks. D1 appear only as a relic foliation in the country rocks; D2 is associated with foliation development and control MCG emplacement. D3 affects both country rocks and MCG producing folding and related mylonitic zones. Even though adiabatic decompression would be responsible for melting processes, fluids circulation along shear zones could have enhanced melting. In this connection, $^{87}Sr/^{86}Sri$ (0.7055-0.7063) of MCG granitoids would indicate interaction with fluids in the source whereas Rb/Sr values between 0.2-0.6 for MCG, that show a positive slope against SiO_2 would be inherent to the evolutionary trends of the crystallizing melt.

PARTIAL MELTING AND RETROGRESSION DURING EXHUMATION OF THE HIGH-GRADE METAPELITES, THE TATRA MTS., WESTERN CARPATHIANS

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Tectonic uplift-related partial melting and retrogression have been recognized in the high-grade metapelites of the Tatra Mts., Western Carpathians (Slovakia) exhumed during Variscan tectonic events (ca 330-300 Ma). Major melting reaction was dehydration-melting of biotite (Bt + Sil + Qtz = Grt $\pm$ Kfs + M), producing a granitic melt and garnet ($\pm$K-feldspar) at ca 800-850°C and 0.6-0.7 GPa. Subsequent cooling is documented by garnet resorption by biotite and sillimanite, indicating a reversal of the prograde melting reaction. Cordierite was formed only in Mg-rich portions of the metapelites during nearly isothermal decompression down to ca 0.4 GPa, by reaction Bt + Sil + Qtz = Crd $\pm$ Kfs + M. Further cooling at nearly constant pressure is documented by retrograde replacement of cordierite by phengitic muscovite and Mg-enriched biotite. Partial melting-related fluids have been encountered in qtz-plg segregations. The fluids involve high density (>42 cm3/mol) CO2-N2 phase with highly varying N2 contents (5-30 mol. %), accompanied by brine (30-80 wt. % NaCl) and disordered graphite. Siderite globules intimately associated with the carbonic fluid and graphite are believed to represent a carbonatite-resembling melt fraction, generated by (a) immiscible separation from crystallizing silicate melt or from supercritical carbonic fluid, (b) reaction of the carbonic fluid with Ca-rich minerals.

CAN COMPOSITIONS OF LEUCOSOMES IN MIGMATITES BE USED AS MODEL FOR COMPOSITIONS OF GRANITES?

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Petrology and geochemistry of migmatites is commonly used to infer processes leading to granite generation. To examine whether trace element compositions of leucosomes are analogues for compositions of pelite-derived granites, we analyzed anatectic migmatites in the aureole of the Harney Peak Granite (HPG), South Dakota, USA. Melanosomes are dominated by biotite, sillimanite, and quartz. Leucosomes have constant Si/Al ratio corresponding to a peraluminous granite. However, they have variable proportions of (sil+qtz)/alkali feldspar that is attributed to instability of feldspar relative to sillimanite due to high a_{HF} in partial melts (Nabelek, *Geology*, 1997). There are strong positive correlations of Ba, Sr, Eu/Eu* and Rb concentrations with the proportion of alkali feldspar. Leucosomes with feldspar have positive Eu anomalies and substantially higher Ba and Sr than the HPG and model pelite-derived melts. This indicates mineral-mineral, rather than mineral-melt equilibrium, between melanosomes and leucosomes that was established during protracted cooling of the migmatites.

RELATIONSHIP BETWEEN GEODYNAMICS AND GENERATION OF MELT IN CENTRAL SPAIN

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This study relates the anatectic generation of in situ granitoids to deformation in the Spanish Central System. The regional rock of the anatectic complexes in Iberia are migmatites, and intelayered with them are found anatectic granitoids. The second phase of the Hercynian orogenys characterized by subhorizontal structures (e.g. shears, folding) probably due to a compressional stage and then to the extensional collapse of the series. Increased local deformation resulted in melting and the generation of in situ granitoids. Among several volatile elements determined by activation analysis, boron is observed to accumulate preferentially in the shear structures affecting the migmatites, therefore helping with the development of anatexis and accelerating the local migration of the melting fraction. This condition plus the existence of a fertile source will be determining factors in the generation of different melt-fraction granitoids.

CRITERIA FOR THE RECOGNITION OF PARTIAL MELTINGE.

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Large (>250 000km2) regions of northern Quebec have undergone anatexis. Four means of recognising partial melting were tested there.1) Macroscopic texture: because melt is mobile it collects in structural sites, e.g. boudin necks, to form leucosomes in metatexite migmatites. If a melanosome surrounds the leucosomes, a local origin for the melt may be inferred. The formation of leucosomes is a robust textural change, i.e. hard to erase by later deformation or metamorphism.2) Microscopic textures: locally thin films of quartz or K-feldspar are present on the grain boundaries, these are interpreted to be remnants of an intergranular melt film. These are the best textural evidence for melt in the source rocks, but are fragile textures easily destroyed by deformation.3) Petrographic evidence: indentification of metamorphic assemblages that imply melt-forming reactions. If extensive, late-stage rehydration of residual rocks occurred, e.g. related to the crystallization of anatectic granite, these assemblages may be destroyed.4) Bulk geochemistry: comparison of the bulk compositions of lower-grade unmelted rocks with those believed to have melted is the best way of recognising the residuum, and source of anatectic melts. This reveals that all the granulite facies metasediments in the southern Ashuanipi subprovince are residual.

PARTIAL MELTING OF AN ACID CRUSTAL MATERIAL UNDER INFLUENCE OF A HEAT OF BASIC MAGMAS (EXAMPLES FROM THE NORTHWEST REGION OF THE UKRAINIAN SHIELD)

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In boundaries of the Northwest region of the Ukrainian shield results of partial melting of an acid crustal material under influence of a heat of basic magmas are investigated. These processes are sharply various on scales. The results of small-scale processes are investigated in exocontacts of the Prutovka sill-like gabbro-dolerite intrusion. Plagio-migmatites and plagiogneisses represent the wall rocks. They were subjected to partial melting with formation of typical textures and consist of corroded grains of oligoclase-andesine, which are cemented by xenomorphic interstitial quartz. Potash feldspar is practically absent. Groups and chains of small-grained hypersthene develop in interstitial area. Partial melting occurred at depths about 1-3 km.

In result of interaction of large (up to 300-450 km^3) volumes of basic magmas with low-crustal material at depths of 20-25 km formed an association of rocks of the Buki massif. It submitted by a rock's set: peridotites and pyroxenites - gabbros and gabbro-norites - monzogabbros and quartz monzonites - hypersthene and amphibole-biotite diorites - granodiorites and granites.

SPECIFIC ENCLAVES IN ACID MAGMAS

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In young (1.5 - 2 mln.y) granites and ryolites in the Northern Caucasus are melanocratic, mostly fine-grained, enclaves of the oval form with diametrs from some cm to 2-3 m. On the contact with sorrounding acid rocks they have quenched zone, width of which depends on the size of enclaves: the bigger is enclaves the less is width of quenched zone. In the everage thickness of such zone is 0.5 cm. Sometimes enclaves have porphyric tex-ture. Phenocrysts are the same as in magmatic rocks (Kfsp, Pl, Q, Bi) and are orientated parallel to the outline of enclaves; sometimes they cross the border magmatic rock - enclave. Sorrounding rocks close to the enclave are more leicocratic then usually and have miarolithic texture. The more probable way of such enclaves formation is liquation (separation) initial melt in the conditions of high fluid concentation.

STAGES OF CRUSTAL MELTING

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By experimental investigation process of crustal melting usually using very fine and well mixed powder of rock. In this case summary surface of particles is very big and they have many points of contact. In the contact usually are two or three particles of different chemical compo-sition; as a result reaction of double exchenge in this case have big rate and generated melt is more or less homogeneous. But in natural condi-tions melting rocks are as a rule coarse-grained and, as a consecuence, summary surface of grains is significantly less as well as quantity points of contact. Usually in contact are only two grains of different chemical composition. Results of our ex-periments show what: 1. minerals melt in the succession Kfsp -> Pl -> Q; 2. on the contact of two minerals form three melts: on the border of each mineral melt have almost the same composition as mineral itself and on the contact of two melts their com-position is near to eutectic of these minerals; 3. melt never become ho-mogeneous even when all minerals are melted. So acid melts generated in natural conditions are heterogeneous from the very begining and process of melting is more complicated then simlpe partial melting.

EXPERIMENTS ON THE FORMATION OF MIGMATITIC AND RESTITIC GRANULITES IN THE LIMPOPO BELT

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The metasedimentary granulites of the Limpopo Belt are migmatitic. Petrographic and field evidence indicate biotite melting via the model incongruent reactions: 1. Bt + Sil + Qtz + Pl (Grt + Melt; 2. Bt + Qtz + Pl (Grt + Opx + Melt; 3. Bt + Qtz + Pl (Opx + Crd + Melt. The reaction textures are variably developed throughout the exposures and zones with prograde biotite and minor leucosome development are interspersed with zones where biotite has been completely consumed to produce granitoid leucosomes and with Grt or Grt + Opx restites. Experiments investigating these reactions as a function of bulk-rock Al_2O_3 content and Mg# in Ti-bearing compositions have produced reaction 1. in metapelites and reactions 2. and 3. in metapsammites. Both removing sillimanite from the starting assemblage and increasing the bulk rock Mg# (50 to 80) raise the starting temperature of the reactions by a maximum of 30 (C. This is in accordance with the above order of the reactions. The experiments also indicate that in Ti-bearing protoliths the biotite melting intervals span a temperature range of at least 80 (C. This suggests that some factor other than bulk rock Al_2O_3 content and Mg# has contributed to the relatively low thermal stability of biotite in the zones of restite development. Experiments using Ti-free compositions indicate that variations in bulk rock TiO_2 content could account for this behaviour.

SE33 Pre-eruptive processes

Convener: Marti, J.
Co-Conveners: Carroll, M.R.; Gudmundsson, A.

MODELLING OF DIKE INTRUSIONS AND VOLCANO GROWTH

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Numerical simulations are used to estimate the contribution of intrusions and extrusions to the growth of volcanic edifices. Dike geometry influences the building of volcanoes in two ways: by lifting up the ground and by determining where an eruption will occur. The ground displacement induced by a dike swarm is calculated at the nodes of a planar grid using the equations of Okada (1986). When a dike reaches the surface, a volume of lava spreads over the ground. The characteristics of every dike (length, width, height and dip) and lava flow (volume, density, aspect ratio and yield strength,) are obtained by balloting amid a pre-established range, according to a tuneable probability law. Adapting the ranges and probability laws, different types of terrestrial and extra-terrestrial volcanic edifices can be modelled. Volcanoes tend to be flat with gentle slopes if dikes are long and thin, come from a large and shallow magma chamber, and give rise to lava flows of low yield strength and aspect ratio. Volcanoes are high and steep if dikes are short and thick, magma chamber is small and deep, and lava flows have high yield strength and aspect ratio. We show how the different parameters control the shape of volcanoes and discuss their potential effect in the evolution of edifices.

CONSTRAINTS FROM DISPLACEMENTS AND TILT DATA ON THE MAGMA CHAMBER AT MERAPI (JAVA)

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Displacement measurements and tilt observations have been conducted on Mt Merapi (Java) near the crater rim and on the lower flanks of the volcanic edifice. Far field data concern the eruption period November 1996 - March 1997. This period includes a vertical explosion on January the 17th, and an increase of the lava dome volume by about 3 $10^6 m^3$. Two GPS campaigns have been carried out at the beginning and at the end of the period. Relative displacements with respect to the reference point show an average downward subsidence equal to 6.5 cm. A multi-component tilt station, installed on the Southeast flanc 3 km from the summit, recorded a continuous signal that expresses the real tilting for a surface with a 10 by 30 m^2 area. After correction of meteorological effects, the relative tilt variation is 11.1 $\pm$ 0.7 μrad in the tangential direction and 0.9 $\pm$ 0.4 μrad in the radial direction. These data are interpreted through a 3D elastic model based on the mixed boundary elements method, and a near-neighbour Monte-Carlo inversion. Final result supports an horizontal elliptic magma source located 8.5 $\pm$ 0.4 km below the summit and 2 $\pm$ 0.4 km to the East of it. This location differs significantly from that proposed from seismic activity analysis. The computed deflation of 11 $\pm$2 $10^6 m^3$ is about three times larger than the observed variation of the lava dome volume. This difference is attributed to rock avalanches and pyroclastic flows on the flanks of the volcano.

TENSILE CRACKS IN LAYERED MEDIA

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Tensile cracks are often employed to model magma intrusion along mid-oceanic ridges or within volcanic edifices. In spite of the large heterogeneity present in these areas, most crack models have been developed in homogeneous media. In this paper the most simple elastic medium is considered, made up of two welded half-spaces characterized by different elastic parameters. The elementary dislocation problem is solved first: explicit analytic solutions are provided for the displacement and stress fields. The problem for a crack entirely embedded in one of the two media is then considered. The singular Cauchy integral equation is solved employing a truncated expansion in Chebyshev polynomials and semi-analytical solutions are given for the displacement and stress fields provided by a constant overpressure within the crack. Then the crack problem for a crack terminating at the interface between the two media is considered: in this case a further singularity appears in the kernel of the integral equation. Finally the problem of a dyke crossing the boundary between two media is considered. The problem is solved by splitting the crack into two interacting open cracks. The stress changes produced by such a crack can explain several seismological, gedetic and geochemical observations in volcanic areas.

A POROUS FLOW MODEL OF MAGMA MIGRATION WITHIN MT.ETNA: THE INFLUENCE OF EXTENDED SOURCES AND PERMEABILITY ANISOTROPY

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A porous flow model for magma migration from a deep source within a volcanic edifice (Mt.Etna) is developed in probabilistic terms. The model is based on the assumption that an isotropic and homogeneous system of fractures allows magma migration from one localized feeding dyke up to the surface of the volcano. The point source model is able to provide a detailed description of eruption site distribution for a few sections of Mt.Etna, but it fails to explain simultaneously the eruption distribution along the mutually orthogonal N-S and E-W sections. The solution is then generalized to deal with extended sources and with anisotropic media, employed respectively to simulate an hypothetical N-S trending fracture system at the base of the volcano or the influence of the regional stress field on the directional probability of dyke opening. The results show that both models are able to explain the presence on Mt.Etna of the N-S trending rift. In particular, the anisotropic model provides the best fits to the N, S, W and E topografic sections. Several features of the eruption distribution on Mt.Etna remain unexplained, however, by a porous flow model and apparently require the intervention of specific structural effects.

AN EMPIRICAL THERMOMETER FOR VESUVIUS MAGMAS

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The estimation of magma temperatures is fundamental to the understanding of pre-eruptive magma evolution and syn-eruptive extraction processes. Mineral-mineral and mineral-melt geothermometers represent the classical approach to the problem. A very powerful tool for the estimation of pre-eruption temperatures (T) and magma compositions (X) is given by the study of melt inclusions (MI) in minerals. In the past few years, a huge amount of T and X data was collected on MI in minerals from the products of several eruptions of Somma-Vesuvius (SV). The whole data set is representative of the wide range of magma compositions, and of the different cooling and storage conditions characterizing the last 4,000 years of SV activity. The data are used to fit an empirical geothermometric law based on the measure of natural T and X couples. Such an approach differs from the previous ones, in which experimentally controlled magma compositions and conditions were used to define the T of crystallization of mineral assemblages.
The use of a natural set of T-X data introduces a number of oversemplifications to the thermometric law. A good fit is however observed for a simple X-T relation, and also between pyroxene composition and T and X of hosted MI. The observed ΔT (T measured - T calculated) results from both analytical indetermination and internal variability in intrinsic magma parameters (P, whole composition, volatiles partial pressure, fO2) of the data set. Despite this, the wide compositional spectrum of analysed products, and their representativity of SV activity, allow to define the T-X field of SV magmas and to reconstruct the evolutive history of shallow reservoirs.

MECHANICAL VERSUS THERMALFLUID-DYNAMICAL EFFECTS IN THE GENERATION OF CALDERA UNRESTS: EXAMPLES FROM CAMPI FLEGREI (ITALY) AND RABAUL (NEW GUINEA)

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Mechanical and thermalfluid-dynamical contributions to unrest phenomena at active calderas are quantitatively evaluated. Mechanical modeling involves the use of analytical and finite element formulations. Thermalfluid-dynamical effects are considered in the framework of 1D and 2D approximations, solved by analytical and finite difference methods. The results shed new light about the influence of caldera structures on the observed phenomena during unrests (seismicity and ground deformations), and on the coupled effect of mechanically induced overpressures and variations in the geothermal fluid circulation regime. Data from Campi Flegrei and Rabaul calderas are analysed in the framework of the obtained results, giving detailed pictures of respective unrest episodes. Furthermore, thermalfluid-dynamical effects have important implications on the evolution of the volcanic system towards critical phenomena, which must be considered for meaningful evaluation of volcanic hazard. Such effects can be only qualitatively evaluated using mathematical models, and should be explored by laboratory experiments. Such experiments have been planned on Campi Flegrei tuff samples, and first results of flow at sub and supercritical conditions are reported.

CONTROLLING INFLUENCES IN THE LATERAL PROPAGATION OF DIKES AND THE POSITION OF FISSURE ERUPTIONS.

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The lateral propagation of dikes requires a balance between the magma supply and the fracture properties and stress condition of the host. Moreover, for the persistent intrusion of laterally propagating, vertically confined dikes connected to an established magma reservoir, that balance must be preserved by an inelastic mechanism which restores the host stress field to one close to the lithostatic condition in all three components. Numerical and analytical models suggest that the location of fissure eruptions associated with laterally emplaced intrusions can be controlled by changes in the number density and depth extent of near surface discontinuity, and by changes in the availability and mobility of groundwater. These affect the stress intensity and apparent fracture toughness at the upper edge of the dike, analytical results giving a variation between 10 - 100 MPa$\cdot$ m$^{1/2}$ in apparent fracture toughness with depth between 0 - 10 km. We present the results of numericalmodelling demonstrating the influence of viscoelastic deformation at depth and of varying boundary stress conditions on the vertical trapping of intrusions. Numerical investigations of the pressure field within laterally flowing magma are included in the analysis of position and timing of fissure eruptions during the emplacement and arrest of a dike. The models indicate that in conditions where lateral intrusion of magma is persistent, a set of renewable conditions within the magma supply system and the host rock must be satisfied and preserved under continued activity.

GROUND DEFORMATION IN A VISCOELASTIC MULTI-LAYERED SYSTEM. A COMPARATION BETWEEN ANALYTICAL AND NUMERICAL SOLUTIONS FOR POINT AND EXTENDED SOURCES

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Analytical solutions for the displacement and stress fields caused by a point source magma intrusion in a multi-layered viscoelastic medium are obtained for different crustal rheologies. Numerical results for an extended source in the same viscoelastic multi-layered system are also obtained using a Finite Element Method. In both cases, the elastic solutions are used, together with the correspondence principle of linear viscoelasticity, to give the solution in the Laplace transform domain. Viscoelastic solutions in the time domain are obtained by inverting the Laplace transform using the Prony series technique. Differences between point and extended sources of pressure are considered.

MODELLING DEFORMATION, POTENTIAL AND GRAVITY CHANGES CAUSED BY A MAGMATIC INTRUSION

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As possible precursors events of volcanic activity, ground deformation and gravity changes are of great interest both in geodetic and geophysical terms, and regularly form a major part of monitoring in active volcanic areas. The high levels of precision attainable in observation techniques used to study these precursor events means that sophisticated models must be developed in order to interpret them and obtain as much information as possible. This information can be used to understand the different physical events involved, and make advances in the field of predictive research. This paper describes theoretical methods developed by this group in recent years for calculating deformation and gravity and potential changes caused by magmatic intrusions, the results obtained to date, and the objectives of future research. In the modelling we consider elastic and viscoelastic layered gravitational media. We study the effects of the medium's properties, of the source and the time dependency of the deformation and gravity and potential changes. We also describe the programmes developed, which perform the model calculations and are available to the scientific community, and how any scientist interested can obtain them.

OVERPRESSURE IN REPLENISHED FELSIC MAGMA CHAMBERS

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In order to quantify the potential for magma mixing to trigger explosive eruptions, we have developed a simple analytical model, based on previous models of magma chamber replenishment, which considers the injection of volatile-rich mafic magma into a chamber occupied by a homogeneous, volatile-rich felsic magma. We assume that the overpressure caused by the injection of new magma is not sufficient to trigger an eruption, for which additional overpressure is required. Two mixing-related mechanims have traditionally been considered to have the potential to generate the additional overpressure: 1) exsolution of volatiles from the felsic magma during forced convection, and 2) exsolution of volatiles from the mafic magma by oversaturation during cooling and subsequent crystallization. Our calculations suggest that exsolution of volatiles from the felsic magma is not an effective mechanism to generate additional overpressure. However, significant overpressuere can be achieved by volatiles exsolution from the mafic magma during its cooling and crystallisation. The time scale between intrusion and eruption considered in our model is of the order of a few days to a few months, which coincides with petrological and geophysical evidence obtained from magma mixing related eruptions. We also suggest that replenishment of shallow felsic magma chambers by mafic magma in most cases does not lead to large scale mixing, as eruption will occur before thermal equilibrium between the two magmas is reached, so that density and viscosity contrasts between the two magmas will remain significant.

MAGMA CHAMBER DYNAMICS IN THE XX CENTURY AT STROMBOLI VOLCANO, ITALY: CONTRIBUTIONS FROM MINERALOGICAL, CHEMICAL AND ISOTOPE DATA

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Since at least 2000 years, Stromboli volcano is characterised by a persistent and moderate explosive activity erupting dark scoriae, bombs, lapilli and ash. This is periodically broken by eruptive crises, including either lava eruptions, or much more violent explosions during which highly vesciculated pomiceous scoriae are also erupted. Rocks are shoshonitic and high-K calc-alkaline basalts. Dark scoriae and lavas are highly porphyritic and have more evolved compositions than pomiceous scoriae, which are nearly aphyric. Petrographic, mineralogical and chemical data indicate a general relatively high P of magma crystallisation, and higher P and T for magma of pomiceous scoriae than that of lavas and dark scoriae. Sr isotope ratios of lavas and dark scoriae erupted during this century exhibit a constant value for about 80 years (0.70626±1, 2 s.e.), followed by a smooth but significant decrease starting some time around 1980 and averaging about 6.10^{-6} $^{87}Sr/^{86}Sr$ per year. $^{87}Sr/^{86}Sr$ values of pomiceous scoriae are lower than the previous ones, and do not appear to have a time dependent covariation. These data, together with chemical data of glass and minerals and magma flux estimates, suggest the recurrent arrivals of mafic magmas in a shallow reservoir, which started, some time around 1980, to be fed by a magma with $^{87}Sr/^{86}Sr$ of the pomiceous scoriae. They have also allowed to estimate a rapid magma residence time ($10<\tau<25$ y.) and a small volume of magma chamber, ranging from $>10^{-3}$ to $<10^{-1}$ km^3.

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A NUMERICAL MODEL FOR TEMPORAL VARIATIONS DURING EXPLOSIVE CENTRAL-VENT ERUPTIONS

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An axisymmetrical numerical model has been developed in order to find the temporal evolution of pressure, the position of the exsolution level, the velocity field, the eruption rate and the amount of erupted material of a shallow, volatile-rich, felsic magma chamber during a plinian central vent eruption. The overpressure necessary to trigger the eruption is assumed to result from crystallization-driven volatile oversaturation. We solve the resulting set of equations using a Finite Element Method. The results obtained show that the pressure at the conduit entrance decreases exponentially as the eruption proceeds. This produces a shifting of the exsolution level, so that deeper parts of the chamber become progressively volatile oversaturated during the eruption. We assess the influence of chamber geometry and the physical properties of the magma on the computed parameters using several numerical examples.

MAGMA ASCENT RATE AND MELT-VAPOR EQUILIBRIUM IN RHYOLITIC MELTS

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Rapid ascent of hydrous magma can result in its arrival at near-surface conditions in a state of supersaturation, possibly leading to explosive eruption. We have performed controlled decompression experiments to investigate the ascent rates required to maintain bubble-melt equilibrium. Rhyolitic melts, saturated with water at 200 MPa, 825°C were decompressed at constant rates of 0.025 to 1.0 MPa s^{-1}, and then rapidly quenched. Decompression at 0.025 MPa s^{-1} allows melt-vapor equilibrium to be maintained (200-80 MPa). One bubble nucleation event occurred and quenched bubble sizes are markedly smaller than predicted from parabolic growth models. We interpret this to reflect interactions between adjacent growing bubbles and bubble size is strongly influenced by bubble number density. At faster decompression rates, melts could not degas in equilibrium when pressure decreased from 200 MPa to 140 MPa, and water supersaturation (ΔP) in melt reached 30 to 60 MPa, with higher values at faster decompression rates. Further pressure release resulted in near equilibrium degasing and ΔP decreased. In each case, ΔP decreased when bubbles exceeded ~10 vol.%. Bubbles nucleated in experiments have mean size smaller than that predicted from equilibrium degassing and number density increases with decompression rate. In explosive eruptions, decompression rates may exceed those investigated and melts may become supersaturated. However, such fast decompressions are expected only for highly vesicular magma, which would aid approach to equilibrium degassing.

RADON LOSS FROM MAGMAS: DEGASSING MECHANISMS AND CONSEQUENCES ON ^{226}Ra-^{210}Pb DISEQUILIBRIA IN LAVAS

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There are strong evidences that freshly erupted lavas have partly or totally lost their radon (e.g. Sato and Sato, Nature, 1977; Gill et al., GRL, 1985). In order to constrain radon loss from hot magmas, high temperature (1350-1500 °C) experiments under atmospheric pressure have been undertaken to study the behaviour of radon in a natural anhydrous andesitic melt. Radon loss was measured by gamma spectrometry, through its short-lived daughters ^{214}Pb and ^{214}Bi, briefly after the end of the experiments. Preliminary results indicate that the diffusion of radon is too slow at magmatic temperatures to explain its loss from the magma. A major gas phase vector (e.g. H_2O) is needed to efficiently extract radon from hot magmas.
Since the most abundant radon isotope ,^{222}Rn, is located between ^{226}Ra and ^{210}Pb in the natural decay chain of ^{238}U, the influence of radon loss on ^{210}Pb-^{226}Ra disequilibria in recent lavas of active volcanoes has been investigated, using a dynamic degassing model. Measurements of ^{210}Pb-^{226}Ra disequilibria at both Stromboli (Italy) and Merapi (Indonesia) volcanoes emphasize the different dynamics of their magma chambers reflected in their contrasted eruptive behaviour: high renewal rate of the magma at Stromboli and short periods of more or less closed system evolution at Merapi.

RADIONUCLIDE CONSTRAINTS ON SHALLOW DEGASSING PROCESSES AT STROMBOLI VOLCANO

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Radon daughters (^{210}Pb, ^{210}Bi and ^{210}Po) are highly enriched in volcanic aerosols and can be used as tracers of magma degassing. We present here data on radionuclide contents measured in the Stromboli plume since 1985. Because of the very low volcanic activity in October 1996, we were able for the first time to separately sample each crater plume, remote sampling of the bulk plume being also performed. These data show that: 1) the plume is not affected by drastic (Po/Pb) and (Bi/Pb) variations within the first few hundred meters from its source, ensuring the validity of remote sampling when the activity does not allow to approach the active craters; 2) there is no differentiation of gases from a crater to another suggesting that the geometry of the feeding system of the volcano is rather simple, gases being directly emitted from a shallow magmatic chamber without significant cooling inside the edifice. Following the previous concept developed by Lambert et al. (EPSL, 1986), we propose a dynamic model of degassing taking into account the variations of radionuclide contents and ratios observed since 1985. This model allows to constrain several parameters related to the volcanic activity such as the escaping time of gases from the chamber, the residence time of the magma and the volume of the reservoir.

LARGE EXPLOSIVE ERUPTIONS IN ICELANDIC CENTRAL VOLCANOES

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Large eruptions in Iceland, which may reach 10-20 cubic kilometres in eruptive volumes, are either effusive and producing basaltic lava, or explosive and producing acid pyroclastics. Most large basaltic lava flows are erupted outside central volcanoes, whereas most large explosive eruptions occur inside them. We propose that explosive eruptions in Icelandic central volcanoes are driven by sudden gas expansion in the shallow source chamber of the volcano. We also suggest that the sudden gas expansion may occur as a result of decompression of part of the chamber, either during slip on a caldera fault or, for a partly molten chamber, because of rapid increase in porosity (due to dilatancy) and associated temporary drop in magmatic pressure when the chamber is subject to shear stress. The reduced magmatic pressure can result in explosive bubble growth in the uppermost part of the chamber and, consequently, can generate an excess fluid pressure that is high enough to drive out large volumes of magma from medium-sized magma chambers.

THE TIMESCALES OF MELT GENERATION AND DIFFERENTIATION: EVIDENCE FROM U-SERIES ISOTOPES

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New U-Th-Ra isotope results are presented from recent eruptions on the islands of Lanzaote and Tenerife in the Canaries, and Santorini. Those from Lanzarote have some of the most primitive compositions found on oceanic islands with MgO = 10.7–12.6%, restricted Sr, Nd and Pb isotopes, displaced towards the HIMU OIB field. Teide-Pico Viejo on Tenerife is a large stratovolcano with silica varying from 42.2 to 59.9% and MgO = 0.34–11.26%. (^{230}Th/^{238}U) = 1.06–1.81 on Lanzarote and 1.004–1.39 on Tenerife. Rocks younger than 8000 years old show ^{226}Ra excesses. The Lanzarote rocks preserve striking trace element arrays that reflect magma mixing processes which appear to have persisted for several thousand years. The end-member compositions have been modelled as ~1 and 5% melts, with the smaller degree melts generated at greater depths, and the melt generation rates were approx $5{*}10^{-4}$kg.$m^{-3}yr^{-1}$. U-series isotope variations in Atlantic OIB indicate that melt generation rates primarily reflect the dynamics of upwelling plume, rather than variations in the age and thickness of the oceanic lithosphere. The (^{230}Th/^{238}U) results for the Teide-Pico-Viejo rocks reflect signficant crustal residence, and one sequence of closed system of basalt to phonolite differentiation may have taken ~200 Ka.

GEOMETRY, MORPHOLOGY AND FORMATION OF HOLOCENE CRATER ROWS IN ICELAND

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Hundreds of crater rows are found within the volcanic zones of Iceland. Some of the eruptive fissures are tens of kilometres long, with as many as hundred individual crater cones. Around 20 eruptive fissures occur in the Veidivötn Fissure Swarm, which forms the southern part of the Bardarbunga Volcanic System in S-Iceland. These include the volcanic fissures formed in the eruptions of Vatnaöldur 871AD and Veidivötn 1480AD. These fissures are discontinuous, but their lengths exceed 65 km, making them two of the longest volcanic fissures in Iceland. The trace of each fissure is marked by tens of crater cones made of ash, scoria and/or spatter, forming rows of different lengths. All crater rows initiate from short, offset segments that during eruptions propagate laterally and link up into longer segments. We propose a model, based on observations of crater rows and dykes, as well as on theoretical studies, as to how the segments link up during the formation of crater rows. The results indicate that most segments propagate as pure extension fractures, and that the way they overlap or coalesce depends on the controlling stress field.

DYKE EMPLACEMENT IN SHIELD-STAGE FORMATIONS OF TENERIFE

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A structural field study was performed on 578 sheet intrusions and 153 faults affecting Anaga and Teno Massifs, where a complex volcanic succession of Tertiary age representing the shield-stage of Tenerife (Canary islands) crops out. The intrusions are mostly subvertical mafic dykes, often emplaced by multiple injection, and whose total thickness is usually less than 2m. A geometrical classification is proposed for dyke tips, which are exposed and preserved in 12% of intrusions. Three differently oriented sets of dykes exist in Anaga Massif (NNE-SSW, E-W, NNW-SSE), while a dominant set trending NNW-SSE is found in Teno. Dyke swarms and other structural features having similar orientations exist also in other islands of the archipelago(1). A minimum value of the horizontal component of extension induced by sheet intrusion is computed using a step of 5° of azimuth and accounting also for the dip of dykes. The values found are at least 300 m (~4%) in Anaga and 270 m (~6%) in Teno; in the two Massifs the maximum peak corresponds to azimuths N75° and N60° respectively, indicating a general prevailing extension in direction ENE-WSW. Preliminary computation of paleostress geometry from inversion of fault-slip data sets suggests the existence of a polyphase brittle deformation due to an extensional stress field with minimum compression principal axis trending NE-SW and WNW-ESE.

(1) Marinoni LB & Pasquarè G. 1994. Tectonophysics, 239: 111-135

OVERLAPPING COLLAPSE CALDERAS

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The surface geometry of most collapse calderas is simple; they are bounded by circular or slightly elliptical ring faults. Many volcanic regions, however, contain several overlapping calderas, giving rise to considerably more complex surface geometries than single calderas. Using the results of field observations, experimental analogue models and numerical studies, we propose that the formation of overlapping calderas is related to the migration of the associated source magma chamber. Our model implies that each collapse of an overlapping caldera partly, or completely, destroys the existing magma chamber. This destruction leads to changes in the local stress field which favour the formation of a new chamber to either side of the previous one, resulting in magma-chamber migration. Field data indicate that the time from magma-chamber initiation to collapse and its migration to either side of the previous one ranges from 0.1-1 Ma.

COLLAPSE CALDERAS DEVELOPED ON STRIKE-SLIP FAULTS

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The distribution and geometry of large collapse calderas are strongly influenced by pre-existing regional tectonics. Several well documented examples of collapse calderas show how parts of the caldera margins coincide with regional faults, with the calderas being in most cases elongated along the main faulting trend. The association of large collapse calderas and strike-slip faults is rather common in continental areas. Such is the case in the Central Andes, where the location and dynamics of most of the Upper Miocene calderas have been controlled by regional tectonics, dominated mainly by strike-slip faulting. Four large caldera structures, Coranzulí, Aguas Calientes, Cerro Galán and Farallón Negro, are located at the intersection of the eastern end of major NW-SE strike-slip fault systems with N-S trending regional faults. We propose that strike-slip faulting creates local extensional tectonics that allow silicic magmas to ascend and acumulate in shallow, large-volume, unzoned, magma chambers. Caldera formation occurs in a single event, with the eruption of large volumes of silicic magma first along the strike-slip fault which behaves as a normal fault during caldera collapse, and then from a ring fault system which propagates from the strike-slip fault.

FIELD, EXPERIMENTAL AND NUMERICAL COMPARISON BETWEEN ANDEAN TYPE AND OCEAN-ISLAND TYPE COLLAPSE CALDERAS

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Collapse calderas include volcanic depressions formed by vertical collapse of the roof a magma chamber, either along well-defined ring faults or piecemal, without well-defined bounding faults. Two extreme types of collapse calderas can be identified from the contrasting structural characteristics of some Andean and ocean-island calderas. Andean calderas tend to form in a single explosive event, are associated with the eruption of hundreds to thousands of km^3 of silicic ignimbrites, and do not show evidence of long periods of volcanic activiy previous to the caldera- forming event. Formation of Andean-type caldeas affects large areas and their associated products rest directly on the pre-caldera basement. Ocean-island calderas are genetically related to pre-existing volcanic edifices and tend to form after long periods of volcanic activity, which may involve the eruption of both mafic and felsic magmas, and several previous caldera forming episodes. Field, experimental and numerical studies have been undertaken in order to investigate the differences between these two types of collpase calderas and to understand their internal structure and the mechanics of their formation.

MAGMA CHAMBER EVOLUTION INFERRED FROM GPS GEODESY OF SOUFRIERE HILLS VOLCANO, MONTSERRAT

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Global Positioning System (GPS) geodesy of six sites proximal to the Soufriere Hills volcano, Montserrat observed from October, 1995 to September, 1996 show non-axially symmetric horizontal displacements, and decreasing subsidence as a function of radial distance from the former topographic high of the volcanic edifice. Foward elastic and finite element models suggest that the surface deformation is caused by an ~1 m wide, shallow NW-trending vertical dike and a deflating Mogi point source at about 6 km depth, in good agreement with independent observations of regional dike widths and pre-eruption magma storage depth. For this period, the surface deformation field is best-fit with a ΔV of $-14 \times 10^6\ m^3$ from the Mogi source and transfer of ~10 per cent of this volume into the upper crust facilitating dike growth. The calculated ΔV is ~1/2 the observed cumulative volume of the andesitic dome up to late July 1996. This difference may reflect the addition of magma to the chamber at 6 km from a deeper source over the observation period.

In July 1996, eight stations were added to the network, including two continuously operating sites on the SW and NE flanks of the volcano. 14 sites now have between 6 and 25 months of accumulated observations. Data from continous sites display variations outside error, which correlate with rapid dome growth, collapse, and pyroclastic flow generation suggesting a fundamental link between surface deformation as measured by GPS geodesy and magma chamber dynamics.

MAGMA TRANSPORT IN DIKE SWARMS

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Magma-filled fractures are the dominant mechanism for magma transport through the Earth's lithosphere. These fissures are grouped in swarms and are thought to be fed from a large magmatic reservoir. We investigate dike initiation, propagation and interaction using two types of laboratory experiments. Dike initiation is studied through the instability between an upper elastic brittle layer and a lower buoyant fluid. The initial topography of the interface prior to instability is found to be of crucial importance in the onset of the instability. This result emphasizes that the initiation of the fractures cannot be neglected in models of their subsequent propagation. To investigate fracture propagation and interaction, dikes are simulated by injecting dyed liquid of different densities and viscosities from a large reservoir at the base of a plexiglass tank filled with solidified gelatin. A constant pressure is maintained in the reservoir and the initial state of stress in gelatin is hydrostatic. Dike interactions occur as a result of the elastic stresses generated during the propagation. The stiffer the solid the stronger and longer range are the interactions. During the propagation of a crack filled with constant source pressure and in which the dominant resistance to propagation is fracture at the tip, we find that the flux increases during the early stages of the propagation after which it is nearly constant. Additional experiments will further examine the relationship between the flux, the velocity of propagation and the viscous effects.

"EASY" HOMOGENEOUS BUBBLE NUCLEATION IN HYDROUS RHYOLITIC MELTS

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To determine the conditions of homogeneous bubble nucleation in hydrous rhyolites, we performed isothermal decompression experiments in an externally-heated pressure vessel. Cylinders of microlite-free rhyolitic glass containing 4.5 or 7 wt % H_2O were first equilibrated at 800 °C and a pressure above the water saturation pressure P_{sat} (≈ 230 MPa at 7 wt % H_2O and 130 MPa at 4.5 wt % H_2O). Pressure was then rapidly decreased to a value $P_{xf} \leq P_{sat}$ and held constant for 2 mins. The experiments were terminated by an isobaric quench at a rate of 200 °C/s. Two contrasted behaviors were observed depending on P_{xf}: at high values of P_{xf}, the samples showed a bubble-free core; at lower values of P_{xf}, homogeneous nucleation occurred in the core of the sample giving rise to a large number of bubbles, identical in size, and with an uniform spatial distribution. The striking result is that homogeneous nucleation occurred at relatively high pressures: ≈ 200 MPa for glasses with 7 wt % H_2O, between 60 and 100 MPa for glasses with 4.5 wt % H_2O. The relative ease of homogeneous nucleation in our experiments (by comparison with the predictions of the classical theory of nucleation for pure water) is presumably due to the effects of volatiles other than water (CO_2, N_2) present in the starting material. Our results suggest that homogeneous nucleation may play a major role in the vesiculation of ascending rhyolitic melts.

LABORATORY MEASUREMENT OF THE ELASTIC AND FRACTURE PROPERTIES OF LAVAS

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The elastic and fracture properties for a variety of lava specimens from Etna volcano have been measured by optimizing several experimental aspects. As regards the measurement of the elastic constants, the repeated ultrasonic pulse technique has been combined with signal amplification and stacking to further reduce noise. An unprecedented overall accuracy of less than 1% has been attained, while anisotropies are found to account for a few percent. The double torsion load relaxation method has been employed on a specially designed very stiff machine to measure the fracture properties in terms of stress intensity factor–crack velocity (K_I–v) data. The latter, measured at carefully controlled STP and humidity conditions, exhibit well-defined fracture propagation regions I, II and III. Measured on a wide range of samples and on a large number of data points, the slope and the position of the stress intensity factor–crack velocity curves exhibit a small scatter, unlike other instances of application of the double torsion load relaxation method in the literature. The consistency of these results, typically within a few percent, suggests that also fracture parameters can be measured with an accuracy adequate to effectively use them for modeling purposes.

THE INTERPLAY OF MECHANICAL AND THERMO-FLUID DYNAMICAL SYSTEMS DURING UNREST EPISODES IN CALDERAS: THE CAMPI FLEGREI CALDERA (ITALY) CASE

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The Campi Flegrei caldera (CFc) is a resurgent, nested structure resulting from two main collapses related to the Campanian Ignimbrite (37 ka) and the Neapolitan Yellow Tuff (12 ka) eruptions. While the structure is affected by a broad subsidence, ongoing local resurgence and unrest occur inside the young, nested caldera structure. The caldera has shown signs of unrest during the past 30 years, with short-term deformations that have generated a net uplift of 3.5 m.
We have performed a mechanical modeling of the monitored ground deformation through time. The modeling, carried out by using a 3D (axisymmetric) finite elements method, takes into account the presence of an active geothermal system at shallow depth. The model includes a central and a peripheral zone. The central zone which represents the resurgent block, has high permeability, while the peripheral zone which represents the caldera floor, is less permeable. The obtained results are able to explain some peculiar characteristics of both ground deformation and seismicity. In particular the ground subsidence is expalined by lateral diffusion of fluids. This hypothesis accounts for both lack of seismicity and variable deformation stile inside and outside the resurgent block, during subsidence.

PHONOLITIC DIKES AT THE LAS CAÑADAS CALDERA (TENERIFE, CANARY ISLANDS): CONSTRAINTS ON THE GEOMETRY AND LOCATION OF SHALLOW MAGMA CHAMBERS

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The Las Cañadas caldera is a multicyclic, composite depression resulting from a complex sequence of vertical collapse events associated with the long history of phonolitic explosive activity in the central part of Tenerife. Several generations of phonolitic dikes, including radial, vertical concentric dikes and cone sheets, are exposed in the caldera wall. A total of 324 dikes have been investigated in the field in order to perform a statistical analysis of their distribution and characteristics. The results of this study indicate that different magma chambers were responsible for generating these phonolitic intrusions, confirming previous geological interpretations of the evolution of the Las Cañadas caldera. A NE-SW regional tectonic trend is also interpreted to have influenced the distribution of dikes and, consequently, the formation of the caldera. Several numerical models, using finite element programs, of magma chambers with different geometries under different regional stress regimes, have been developed in order to characterise the (local and regional) stress-fields necessary to produce the observed distribution of phonolitic dikes in the Las Cañadas Caldera. In addition, several features of magma chamber evolution and dike injection have been deduced theoretically from this study.

PHASE EQUILIBRIA OF Na-RICH PHONOLITES FROM MONTÃNA BLANCA, TENERIFE.

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The 2020Bp eruption of Montãna Blanca, Tenerife produced a series of glassy Na-rich phonolitic lavas. The lavas are characterised by fractional crystallisation of an assemblage dominated by alkali feldspar but also including sodic clinopyroxene, biotite, magnetite, ilmenite and apatite. FeTi oxide geothermometry indicates an eruption temperature near 800°C for the phonolites. In order to better constrain the sub-volcanic conditions from which the phonolites originated we have studied the experimental phase equilibria in water saturated and water undersaturated (aH_2O = 1.0 and 0.5) experiments using powdered samples of the natural phonolitic glass over a range of pressures (0-3Kbars), temperatures (750-950°C) and oxygen fugacities (FMQ to NNO+1). Water-saturated phase relations at NNO+1 show a near liquidus (820-850°c) crystallisation sequence of Mt, Biot, Ap (all steep in P/T space, and first observed within ~10°C of each other). Sph, Na-Cpx and Fspr occur at somewhat lower temperatures (<800°C) and their stability is more sensitive to $P(H_2O)$. Nepheline is the only other phase observed and is limited to temperatures below 770°C. Initial results at lower (FMQ) oxygen fugacities suggest that Bt and Mt stabilities depend strongly on oxidation state, with lower liquidus temperatures under more reducing conditions. Experiments now in progress will verify this and extend work to water undersaturated conditions.

DETERMINATION OF H_2O, F, Cl AND S IN VOLCANIC GLASSES FROM THE A.D. 79 VESUVIUS ERUPTION, SOUTHERN ITALY

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F, Cl and S contents, as well as major elements, of both white and grey pumice mesostases from the 79 A.D. eruption of Vesuvius, were determined by electron microprobe. Water measurements were carried out by infrared spectroscopy. Taking into account magma evolution by fractional crystallisation and the constraints due to theoretical solubility limit of each volatile species, the lower amounts of water and sulphur in natural samples suggest that they undergo to degassing during eruption. Fluorine and chlorine seem to follow a different behaviour. In general, fluorine composition seems to be linked to the crystallisation of mineral phases containing this element in their structure, whereas the variations of chlorine contents seem to be determined by more complex processes. Generally speaking, the different amount and behaviour of volatile species in the volcanic products from Avellino (36000 years old) and 79 A.D. eruptions could indicate a different depth of the two magmatic systems.

PRE-ERUPTIVE VOLATILE (H_2O, F, Cl and S) CONTENTS OF PHONOLITIC MAGMAS FEEDING THE 3600 YEARS-OLD AVELLINO ERUPTION FROM VESUVIUS, SOUTHERN ITALY

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Glass inclusions and mesostases from white pumice and mesostases from grey pumices of Avellino eruption were studied to determine both the pre-eruptive contents and the syn-eruptive behaviour of volatile species. Major elements, halogens and sulphur were measured by electron microprobe and water by micro-FTIR. Both glass inclusions and white pumice mesostases show phonolitic composition, whereas grey pumice mesostases present a wider compositional range. According to the petrologic approach, fluorine and chlorine present similar contents both in glass inclusions and in white pumice mesostases, showing a scarcely volatile syn-eruptive behaviour, whereas white pumice mesostases have lower sulphur and water contents than inclusions. A wider S variability, moreover, characterises the grey pumice mesostases, whereas similar water contents were determined in both white and grey pumice mesostases. Combining the volatile abundance of glass inclusions with the appropriate experimental solubilty studies, we suggest that the whole magmatic system was saturated in S and Cl, and possibly in water, prior to the eruption.

RADON NETWORK AT PITON DE LA FOURNAISE, REUNION ISLAND: SEISMIC CRISES ANTICIPATED BY ^{222}RN PULSES

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Piton de la Fournaise volcano is equipped by a dense ^{222}Rn monitoring network which works continuously since 4 years. It consists of 26 radon stations, six of which were transmitted by radio to the observatory. The remaining stations are so-called autonomous stations the data of which were stored in the field and recovered every 4 - 6 weeks in quiet periods and much more often during active periods of the volcano. Time resolution of radon determination is 1 minute for radio transmitted stations and 1 hour for autonomous ones.
Unfortunately, the actual radon network was operative only after the last eruption and radon outgassing could not been monitored during an eruptive event. Nevertheless, in Nov. 1996 and Aug. 1997, two seismic crises happened at Piton de la Fournaise and since July 1997 the seismic activity increased by a factor of 5 compared to early 1997.
The Nov. 96 crises was preceded by a radon pulse up to 50 times background level 36 hours before the crises and observed by 6 radon stations. The smaller crises in Aug. 1997 was preceded by radon pulses 5 days and several hours before the crises and observed on 3 stations.
Overall, an increase of radon activity is observed since July 1997 jointly with the increase of the seismic activity of Piton de la Fournaise volcano. No significant variation of radon activity was observed due to climatic variations as pressure, temperature, humidity and rain fall. Perturbations by lightning in the beginning could be avoided by efficient shielding of the photo electric cells of the radon probes.

ELLIPSOIDAL VS. SPHERICAL MODELS FOR MAGMATIC INTRUSION SOURCES

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Ground deformation is a phenomena that has long been associated with magma injection in volcanic areas. As a result, many such areas are well monitored today, and their activity status is based, at least in part, on the size and pattern of that deformation. We have developed a source model for a prolate ellipsoid, and compared it to spherical sources, both elastic and viscoelastic, for an active volcanic area (Davis, 1986; Yang and Davis, 1988).
These volcanic source models were compared using a genetic algorithm inversion technique and data from Long Valley caldera, California. A genetic algorithm (GA) is a directed search technique which combines the principle of survival of the fittest with a prescribed random information exchange. Topographic data from a trilateration network consisting of both two-color electronic distance meters (EDMs) and leveling measurements has been in place since 1989 in Long Valley, when the second episode of uplift within a span of 10 years began. The GA employed these accurate measurements of deformation for Long Valley to search for and compare the optimal source mechanism, ellipsoidal or spherical, in conjunction with other potential sources such as faulting.

CONSTRAINTS ON THE TIMESCALE FROM NUCLEATION TO EMANATION OF VOLCANIC GASES

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Volatile Cl and S compounds of Bi, Po and Pb fractionate into the gas bubbles of vesicular magma and reach the surface on time scales that are similar to the half lives of ^{210}Bi, ^{210}Po and ^{210}Pb. Using published values (Lambert *et al.*, 1985) for gas transfer rates into magma, appropriate physical parameters and a suitable mathematical model, the time elapsed since bubble nucleation can be estimated. Fumarolic gasses from Momotombo (Nicaragua) have been collected with stainless steel condensers and analysed for ^{210}Bi, ^{210}Po and ^{210}Pb disequilibrium. The data show very high values and considerable differences. The Momotombo fumaroles have been active since the last major lava eruption in 1906 and have temperatures between 400°C and 900°C whenever they were measured over the past decades. In these circumstances it is reasonable to assume that the transfer time of gas from the magma surface to the mouth of a fumarole is less than an hour, and that the gas has not interacted with aged fumarole deposits. The data can be reconciled with the model predictions for bubble rise times of ca 3 weeks, assuming a degassing column of 500 m and small variations in the element transfer rates into the gas phase.

NH4 Volcanic hazards: field studies, instrumentation and observation networks (co-sponsored by SE)

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GPS MEASUREMENTS IN THE NEAPOLITAN VOLCANIC AREA

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Among the institutional activities of the Osservatorio Vesuviano, there is the surveillance of the Neapolitan volcanic area (Mt. Vesuvius, Phlegrean Fields and Ischia island) which is carried out also through the study of ground deformations. In the last two years, a GPS network in the above mentioned area was established. In Mt. Vesuvius area a GPS test was carried out in order to verify the possibility of the installation of a network of GPS permanent stations. A quality control of the acquired data was made with the QC software by UNAVCO, then the processing phase was carried out using two different programs (BERNESE and GEOTRACER) for a cross control of the results. In the Island of Ischia three different techniques (static, fast-static and real-time-kinematic) have been used to get a first set of coordinates and to perform a comparison between the three metodologies. GPS data of the Phlegrean Fields are still in processing. The results for Mt. Vesuvius area and the Ischia island are presented and discussed.

GPS AN DIGITAL PHOTOGRAMMETRY FOR MONITORING GROUND DEFORMATIONS ON A VOLCANIC AREA.

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In September 1996 an airborne GPS-photogrammetric project was performed over the Vulcano island (Aeolian Island Arc) in order to experiment a fast and accurate procedure for an aerial photography mapping application for ground deformation monitoring. The use of GPS observations for establishing the position of the photo centers at the instant of exposure, reduces the number of required ground control points; the processing of the images in digital form, from image scanning to the Digital Terrain Model generation, allows for time reduction when automatic procedures can be successfully applied. The data collected during the experiment, that is images at 1:5000 and 1:10000 scale, were digitized at a resolution of 1000 dpi, and analyzed using the Helawa system which adopts a correlation algorithm working at subpixel level, with a resulting ground resolution of about 5 cm. GPS kinematic camera positions were obtained installing two receivers on the aircraft and three reference stations on the ground which continuously operated during the flight mission. GPS kinematic solutions were obtained using both commercial and scientific software's with OFT capabilities. The experiment allowed to define the geometry of the calderic structure with an accuracy at the decimeter level, confirming that the aerial photogrammetry, even if generally less precise than geodetic surveys, gives the possibility of defining with higt spatial resolution the strong deformations process of volcanic area.

TSUNAMIS GENERATED BY VOLCANIC EXPLOSIONS: DATA FROM 1996 ERUPTION IN KARYMSKOYE LAKE (KAMCHATKA, RUSSIA)

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The 1996 subaquatic explosive eruption in Karymskoye lake (4 km across, maximal depth 70 m) generated multiple tsunamis. We document the tsunami effects and runup. These data enable determination of a law of attenuation of runup (wave) height for "explosive" tsunamis, which is compared with theoretical modelling. For the proximal zone, to radial distances (r) up to 1.3 km, the runup height (R) shows rapid attenuation (from >30m to 8 m) with distance as $\log R = -0.56 \log[r] + 5.8$. For the distal zone, $r > 1.3$ km, R decays more slowly (from 8m to 3m) as $\log R= -1.98 \log[r] + 16.3$. Rapid decay in proximal zone suggests that in the near field of the explosion the tsunami propagate as a collapsing wave with discontinuous change in height. The break-in-slope of the runup plot at 1.3 km suggests that the tsunami propagate further as a decaying one-dimensional wave in a channel of approximately constant width.

TSUNAMIS GENERATED BY LARGE SCALE FAILURES OF COASTAL VOLCANOES - EXAMPLES FROM KURILE-KAMCHATKA REGION, RUSSIA

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Our investigation of Harimkotan volcano (Kurile islands) has shown that tsunami up to 20 m high, witnessed during its 1933 eruption (Miyatake, 1934), was generated by volcanic debris avalanche which entered Pacific Ocean. Subaerial part of the avalanche deposit forms a broad hummocky fan (max thickness 10-20m; length 7 km; area 20 km^2; volume 0.4 km^3). The avalanche smashed the ocean along 8 km of coastal line. It was formed as a result of large scale failure of the volcanic edifice 1213 m high. Multiple (>4) prehistoric debris avalanche deposits spreading offshore were discovered on the island. That is the evidence that tsunamigenic failures, similar with the 1933 event, repeatedly occurred in the history of the volcano. Youngest of them were 1100 and 2000 C^{14} years ago. Failure of Avachinsky volcano (Kamchatka peninsula) in the end of Pleistocene produced debris avalanche with the volume approximately 10 km^3. The avalanche travelled the distance more than 24 km and entered Avachinsky Bay along the shore line 5 km long. Thickness of the avalanche deposit in modern sea cliff is more than 50 m. Generation of strong tsunami was inevitable in that situation.

CONTINUOUS GRAVITY RECORD AT MOUNT VESUVIUS: A TOOL TO MONITOR ITS DYNAMICS

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High precision relative and absolute gravity measurements are periodically carried out on Mt. Vesuvius (Southern Italy) to monitor gravity changes associated with its dynamics. Since 1987, a permanent recording gravity station also operates on the volcano aimed at a continuous record of the "non-tidal" gravity changes.
Here we focus on the results of more than 3 years of gravity records starting from 1994. Tidal analyses have been carried out on the data-set using several methodologies. The ocean and atmospheric effects have been taken into account for the computation of the gravity residuals.
The time behaviour of the main tidal parameters and of the gravity residuals have been compared with some features of the vesuvian dynamics, mainly with the temporal gravity changes detected by absolute and relative gravimetry.

MICROGRAVITY MONITORING OF PITON DE LA FOURNAISE VOLCANO (LA RÉUNION)

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In order to achieve a greater accuracy in the gravity monitoring of Piton de la Fournaise volcano, we carried out four microgravity surveys from 1993 to 1997 to complement the existing network. The complete network now contains more than 100 stations distributed on the volcano. A reference base line was established to check the calibration of the meters during each survey. The gravity and geodetic measurements are now simultaneously performed using several high resolution Scintrex CG-3M gravity meters and Ashtech GPS receivers for kinematic positionning. An interactive computer program including precise earth tide model and adjustment procedure of gravity observations has been especially designed to process Scintrex CG-3M gravity data. The final accuracy obtained on gravity values on this repetition network is estimated to be in order of 15 to 20 μGal. To detect possible shorter term variations associated with the volcanic activity, we have also set up two CG-3M meters located at different sites of the volcano. Meteorological recordings are also performed simultaneously in order to remove external pressure and temperature effects from the gravity signal. We present here the microgravity data acquisition and processing. We discuss our first results and their implications for the understanding of the magmatic system of Piton de la Fournaise volcano.

SUBSURFACE MASS REDISTRIBUTION DETECTED BY MICROGRAVITY STUDIES AT MT ETNA, 1995-96

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Gravity changes observed by regular migrogravity surveys indicate that significant magma movement continued within Etna's central feeding system between 1994 and 1996, a period including the 1995-96 explosive activity at the summit. Early magmatic changes were detected along Etna's Summit Profile when, between September 1994 and October 1995, some 2 x 10^{10} kg of magma were intruded beneath the summit region at about 1000 m a.s.l.. The positive anomaly due to this intrusion disappeared during the following nine months (coinciding with violent strmbolian activity at the summit), while a new positive anomaly (of about 2 x 10^{10} kg) was detected below about 1000 m a.s.l. and within the 1989 fracture system. None of the anomalies was accompanied by significant changes in ground elevation or seismicity, suggesting a passive mechanism of injection. At the same time, measurements along the E-W Profile detected some 1.5 x 10^{11} kg of magma accumulating 2-3 km below sea level. Magma thus appears to be infiltrating the 1989 fracture system, which fed major flank eruptions in 1989 and 1991-93. The 1989 fracture system must therefore be considered active and, hence, a favoured site for flank eruptions in the near future.

PRECURCURSORS TO THE PLINIAN ERUPTIONS OF THERA (1628 BC) AND VESUVIUS (79 AD): DATA FROM ARCHAEOLOGICAL SITES.

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Stratigraphic evidence from the Bronze Age settlement of Akrotiri (Santorini, Greece) and the Roman towns of Pompeii and Herculaneum (Vesuvius, Italy) has been used to investigate the scale of pre-eruptive phenomena before the plinian eruptions of Thera in 1628 BC and of Vesuvius in 79 AD. Both eruptions were characterized by precursory seismic activity, but with very different magnitudes and impact on local populations. The Akrotiri settlement was badly damaged by strong earthquake(s), forcing an early evacuation of the island and destroying Akrotiri before the eruption began, as shown by the fallout pumice bed which mantles the ruins and has preserved the state of destruction. No clear evidence exists of intense, destructive seismic activity immediately before the AD 79 eruption of Vesuvius, and only low-magnitude shaking has been recorded. Indeed, weak seismicity would account for local populations being caught unawares by the eruption. None of the deposits at either volcano show evidence of major precursory volcanic phenomena (magmatic or phreatic). In both cases, the main eruption was preceded by low-energy phreatomagmatic pulses, strongly suggesting that pre-eruptive behaviour was conditioned by diffuse hydrothermal activity.

KINEMATICS AND MECHANICS OF LATERAL COLLAPSES ON OCEANIC ISLAND VOLCANOES, AND THEIR EFFICIENCY AS TSUNAMI SOURCES

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Giant lateral collapses and debris avalanches on the flanks of oceanic island volcanoes, with volumes of 100 to 2000 cubic kilometres, have been linked to the formation of giant tsunami, most notably by Moore et al. who have identified deposits from such tsunami in the Hawaiian archipelago. Similar deposits have recently been found by us on volcanic islands in the Atlantic ocean. If deposits of this type are generated by lateral collapses, then these must be more efficient tsunami sources than continental slope sediment failures of similar volume. Our studies of large-volume debris avalanche deposits on Gran Canaria and of an aborted rift flank collapse on the island of El Hierro indicate that flank collapses on these islands begin by rapid sliding of a single rigid mass. Motion breaks the mass into large blocks whose relative movements on intervening faults are small compared to the dimensions of the blocks and to the bulk displacement of the failing mass (~ 100 m as compared to at least 5 km in the case of a displaced block terrane on Gran Canaria). We therefore consider that models of tsunami generation by sliding blocks (which indicate highly efficient tsunami generation) are more closely applicable to oceanic island lateral collapses than models of tsunami generation by sediment flows.

GEOMAGNETIC PREDICTION OF VOLCANIC ERUPTIONS

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The structural heterogeneity and the dynamics of the plumbing system of each volcanic edifice can strongly condition typology and characteristics of the precursory signals of eruptions. Traditionally, ground deformations and seismic activity studies are used to detect such precursory signals. However, both methods point out local phenomena such as a rupture along a fault plane or local deformations along a fissure system. These techniques can be usefully supported, for monitoring volcanic activity, by the magnetic method that integrates the effect of a phenomenon over a large volume. Variations of the magnetic properties of the rocks generate a wide variety of magnetic signals that can also appear a long time before eruption and are generated by different mechanisms. In particular, a meaningful change of magnetic field is expected in the case of an eruption of a basaltic volcano as Mt. Etna containing a large amount of magnetic minerals, which modify their magnetization when subjected to temperature variations or when submitted to a mechanical stress, In order to evaluate the suitability of magnetic surveillance to volcano prediction on Etna, we analyzed two historic series of magnetic data recorded there: i) during the 1981 eruption and ii) immediately after 1989 eruption. Moreover, we examined time series associated with the intense explosive activity of Etna in 1995 summer provided by the present permanent magnetic network which was set up between 1994 and 1995.

THE SOURCE PARADIGM OF THE VOLUMINOUS IGNIMBRITES OF THE SIERRA MADRE OCCIDENTAL, MEXICO.

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The Sierra Madre Occidental (SMO) covers at least 360,000 km^2 in Northern Mexico and is the largest continuous ignimbrite province in the world. Its magmatic evolution can be divided into the Lower Volcanic Complex (LVC) and the Upper Volcanic Supergroup (UVS). The LVC consists of intermediate-silicic volcanic and plutonic rocks of Upper Cretaceous-mid Tertiary age, while the UVS is essentially an ignimbrite plateau of Eocene-early Miocene age. A conservative estimate of the physical volume of the SMO ignimbrites is about 360,000 km^3 (1,200x300x1 km). However, only a few calderas have been identified in the province, either because additional calderas have been covered by younger ignimbrite sheets, or because fissures, with the NNW regional orientation of the Basin and Range faults, served as conduits for much of the ignimbrite. These fissures are several kilometers long and are represented by a combination of (1) rhyolite dikes emplaced along extensional features, such as the flexure zone in the shoulder of half-grabens, and (2) co-ignimbrite lithic-lag breccias with a linear alignment several km long and also oriented NNW. Both types of source may have occurred in the SMO, with fissures predominating in areas more affected by extension, and calderas occurring in relatively less extended areas.

NEW GRAVITY SENSORS AS PROBES OF VOLCANIC ACTIVITY

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A new and smaller absolute gravimeter and a new gravity gradient sensor will be described together with their relevance to volcanic monitoring. Gravity changes have proven useful in the monitoring of volcanic activity. The demands of portability in a difficult and remote environment have here-to-fore caused relative gravimeters to be the major investigative tool. Instrumental drifts and tares however require closure of measurement loops with these instruments in order to approach useful precisions in the 10-20 μ gal range. A new and smaller absolute instrument which is under development at JILA will be described which is intended to ameliorate some of these problems. In addition a low cost (5-10K) and truly field-compatible (i.e. one person portable; weight < 17 kgm) gradiometer intended for permanent instillation at sites near regions of volcanic activity will be described. Such an instrument would provide continuous registration of mass motions at the "equivalent" 10-20 μ gal level of sensitivity. Used separately or in combination these under-development gravity sensing instruments should help us better to "see", and thus understand, the details of magma motions.

SELF-POTENTIAL STUDIES OF HYDROTHERMAL SYSTEMS AND STRUCTURE ON MISTI AND UBINAS VOLCANOES, S. PERU

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Misti stratovolcano (16:18°S, 71:24°W, 5822 m), 14 km NE of Arequipa (pop. c. 900,000) contains two concentric summit craters, in the younger of which is a small lava dome with fumarolic activity. A self-potential (SP) investigation over 100 km^2, combining long radial profiles, has revealed two kinds of zones when SP values are plotted against altitude. The first shows a linear, inverse correlation between SP and elevation, a trend expected from standard hydrogeological models. The second instead shows a direct correlation, suggesting a hydrothermal system. The boundary between hydrological and hydrothermal zones is circular, about 6 km across, and correlates well with the edge of an old caldera, whose walls might limit the lateral extent of a convective system of rising gas. Ubinas stratovolcano (16:22 °S, 70:54 °W, 5672 m) is truncated by a summit crater, 1.2 km across, which partly overlies another deep crater (500 m across, 200 m deep) whose fumarolic activity has become more vigorous since December 1995. Detailed SP and thermal infra-red investigations (to 15 cm depth), involving more than 5700 measurements inside the large summit crater, do not show any anomaly, perhaps due to the absence of an extensive fracture system. Such a closed-system interpretation is consistent with the leakage of pressurised gas that can easily be heard more than 1 km distant.

GEODETIC MONITORING OF DYKE EMPLACEMENT, SLOPE INSTABILITY, AND FAULT CREEP AT MOUNT ETNA

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Dyke-induced rifting events have occurred on the east flank of Etna four times over the past fifteen years, in 1983, 1985, 1989, and 1991. Regular surveying of a geodetic network, established on the upper flanks of the volcano in 1981, has revealed lateral displacements ~ 1m associated with each event. This matches the average widths of prehistoric dykes exposed in the walls of the Valle del Bove sector collapse structure. The largest cumulative movements are observed adjacent to the back wall of the Valle del Bove, where the 1km high cliff has been displaced eastwards by over 5m since 1983. Strains accumulating in the upper levels of the volcano appear to be released over time by aseismic creep and periodic earthquakes on faults bounding, and enclosed within, the mobile eastern sector of the volcano, which is being displaced seawards at centimetric annual rates. Observed deformation was minimal during the four years following the end of the major effusive eruption of 1991-93. However, extension between 1996 and 1997 argues for the emplacement of fresh magma into the same fracture system which fed the 1991-93 eruption. Results from contemporaneous microgravity surveys support this interpretation, and highlight the importance of integrated, multiparameter monitoring to eruption forecasting.

CROSS-CORRELATION BETWEEN VOLCANIC TREMOR AND SO_2 FLUX DATA FROM MT. ETNA VOLCANO

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Significant hints on the current eruptive state of a volcano may be inferred from both geophysical and geochemical monitoring. In this work volcanic tremor and sulphur dioxide emissions, measured during the period October 1987 - July 1995 on Mt. Etna, were analysed. The aim is to give a quantitative and systematic description of the correlation between the two data series and to evaluate a possible association to the volcanic activity of Etna. On this purpose a cross-correlation analysis was performed. The results indicate that volcanic tremor and SO_2 time series have a similar increase in correspondence of the largest eruptions. Hence, in the strong eruptive episodes, volcanic tremor and SO_2 flux seem to originate from a common physical mechanism related to magma dynamics.

PYROCLASTIC FLOW HAZARD IN THE MAXIMUM EXPECTED EVENT AT CAMPI FLEGREI (ITALY)

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Numerical simulations of pyroclastic flows generated by the collapse of an eruptive column in the maximum expected event at Campi Flegrei (Italy) are performed in order to estimate the associated hazard. A multiphase and multicomponent model based on transport theory is adopted. The solid phase consists of particles of two granulometric sizes and densities, whereas the gas phase is composed by the magmatic gas (H_2O) and the atmospheric air. The simulated event is assumed similar in intensity to the "Agnano Monte Spina" ($\approx$ 4Ka) and the "Pomici Principali" ($\approx$ 10Ka) eruptions. A parametric study is performed to analyze the effect of the initial water content, vent diameter, and topographic profiles on the flow propagation, and to define the conditions at the vent causing the pyroclastic flows to overcome the topographic reliefs (Posillipo's Hill) located between the Phlegraean Fields and the city of Neaples. Results show the important role played by the topographic relief in reducing the pyroclastic flow hazard. Only for particular input conditions and vent location the pyroclastic flow may overcome the topographic relief, reaching the neighbours of Neaples.

NUMERICAL SIMULATION OF A POTENTIAL DEBRIS AVALANCHE IN MONTSERRAT, LESSER ANTILLES

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The Soufriere Hill's volcano in Montserrat, Lesser Antilles, has been erupted since July 1995. The extrusion of lava lead to the formation of a new dome in the active English's Crater. The evolution of volcano's activity could lead to dome collapse generating a tsunami. Preliminary simulations, assimilating the debris avalanche to a fluid flowing in a U shape valley, lead to waves ranging from 1 to 2 meters reaching Guadeloupe island, situated 50 km at the Sud-Est. We have developed here a numerical debris avalanche flow model, based on more physical assumptions. The debris avalanche is described by a Coulomb type friction law. This model solves vertically integrated long wave equations. A sliding mass of about 100 millions of cubic meters is flowing to the East towards the sea. The simulation is done by using a MNT of the Tar River Valley, Montserrat. We show that the topography and the mechanical behaviour change significantly the velocity and the front height of the mass reaching the sea. The height of the simulated tsunami is reduced.

DEVELOPMENT OF A MIXED-MODE GPS GEODETIC NETWORK AT SOUFRIERE HILLS VOLCANO, MONTSERRAT

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We have developed and maintained a mixed-mode GPS geodetic network for monitoring Soufriere Hills volcano. Network evolution may be divided into four phases: (1) network establishment with L1-carrier phase observationsduring August 1995; (2) daily L1/L2 observations between October 7, 1995 and December 29, 1995; (3) network densification to 14 sites with nearly daily L1/L2-carrier phaseobservations between May 14, 1996 and August 8, 1996; (4) installation of two continuous GPS sites in July 1996 and intermittent reoccupation of all network sites from September 1996 to present. Initial GPS observations were made in August 1995 using two Trimble GeoExplorer 6-channel, L1 carrier phase receivers with internal antennas. Dual-frequency GPS observations began on October 7, 1995 using three 9-channel Trimble 4000SSE receivers with Trimble 4000SSE/SST L1/L2 antennas with flat ground planes. Dorn-Margolin chokering antennas were substituted in May 1996. The three receivers were moved among the 6 sites (one held fixed), and data were collected using a 30s sync rate for between 16 to 24 hr per UTC day. Continous GPS data from Montserrat is compared with other tropical sites to clarify possible long-term trends and to identify periodic volcanic behavior. A phase dispersion minimization (PDM) algorithm is used to analyze the time series in addition to the standard Fourier Transform techniques. Advantages of PDM are: (1) no waveform is assumed; and (2) uneven sampling is more easily handled.

GROUND DEFORMATION MONITORING AT SOMMA-VESUVIUS AND CAMPANIAN VOLCANIC AREA (ITALY).

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We present an integrated ground deformation network aimed to monitor volcano-tectonic movements in the area of Neapolitan volcanism. It covers an area of more than 10000 km2, including the volcanic centers of Somma-Vesuvius, Campi Flegrei caldera and Ischia island. It includes levelling and EDM networks, as well as GPS periodic and continuous measurements. The scope of the network is twice: monitoring ground deformations in volcanic areas, and studying the complex tectonics of the Campania Plane, a graben-like structure in which all the Neapolitan volcanism is concentrated, as related to the tectonics of Southern Apennines. The monitoring network consists of a larger scale, levelling EDM and GPS network covering the whole Campania Plane, connected to the stable areas of Apennines, and smaller scale networks aimed to accurately monitoring the Somma-Vesuvius volcano, the most dangerous over the World because of its high urban development. The Somma Vesuvius is monitored by an over 200 km long levelling network, by periodic EDM and GPS measurements and by a small network of continuously monitoring GPS instruments. The main features of the networks, as related to the monitoring capability, are presented, as well as the most recent measurement results. The performance and efficiency of the networks for the interpretation of data in terms of volcanic and tectonic models are also discussed.

RETROSPECTIVE IDENTIFICATION OF PHENOMENA CORRELATED WITH VOLCANIC ERUPTIONS

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One of the main tools in phenomenological studies is the identification of correlations among different processes. This is essentially effected in retrospective with the specific aim of finding a positive result, and that leads to a parameter optimization which introduces a bias, so far essentially disregarded, in the significance level of the results. If the correlation can be validated in a forward study in which parameters are kept fixed, such a bias is irrelevant. Unfortunately, forward studies are mostly impractical in Geophysics since they would require to wait for a very long time. Unbiased estimates can be obtained in retrospective if each of the optimal choices is properly identified and accounted for. An application of this correction to the apparent seismic "precursors" of Mount Etna volcano flank eruptions shows that these are most likely to be artifacts of the retrospective optimization.

AN INTEGRATED MONITORING PROJECT FOR THE MODELLING OF MT. MELBOURNE VOLCANO INTERNAL DYNAMICS (ANTARCTICA)

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At present, volcanic activity of Mt. Melbourne consists of low temperature fumaroles and ground heating, but studies on pyroclastic falls suggest that the latest eruption occurred in the last few centuries. Ground deformation and internal dynamics studies began in 1988-89. A physical volcanology observatory, consisting of tilt and seismic permanent networks together with GPS and gravimetric periodic networks were set up. In 1996 a multidisciplinary research programme grouping the previous activities and aiming at modelling the internal dynamic processes of the volcano started. Seismic, tiltmetric, GPS, gravimetric and magnetovariational measurements are underway in order to analyse the space-temporal pattern of the various parameters defining the state of "normality" of the volcano. Previous magnetic and gravity data were used to perform modelling studies. Furthermore, the development of a volcano control strategy, which may be adopted for other volcanoes with similar problematics but greater risk, is amongst the aims of this project. Multidisciplinary data collected during the last Italian Antarctic Expeditions will be discussed together with first results and future developments.

THE VOLCANOSEISMIC CRISIS OF 1996-1997 IN NISYROS, SE AEGEAN SEA, GREECE

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After a repose time of several years an intense, shallow seismic activity started by the end of 1995 in the volcanic region of Nisyros Island. By the end of October 1997 hundreds of shocks were recorded, the largest one being that of 27 August 1996 with M_s=5.3. The activity is highly clustered in space and time while the b-value of the magnitude-frequency relation was found equal to 1.67. Similar b-values were determined from the Nisyros seismicity of 1911-1980 and from an 1997 data set of microearthquakes. These seismicity properties seem to be a characteristic of the region rather than precursor of a forthcoming eruption and make Nisyros similar to other large calderas of the Earth where the episodic unrest with local swarm-like earthquake sequences separated by months or years is a typical pattern that do not culminate in a volcanic eruption.

MONITORING GROUND DEFORMATION AT THE DECADE VOLCANO GUNUNG MERAPI, INDONESIA

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Pressure changes within a volcano lead to deformations of his edifice. To discriminate local and regional ground movements, four deformation stations with clusters of continuous borehole tiltmeters have been installed at the hillsides of Gunung Merapi. In addition, recording local environmental parameters allows the recognition of interfering local tilt signals. First analyses of the data records show: The significant tidal variations of the tilt signal validate the successfull coupling between the instruments and their surroundings. Transient tilt signals correlated to rainfalls are probably caused by poroelastic deformation of the hillsides. Four volcanic events occurred during the observation period; all of them were accompanied, if not triggered, by heavy rainfalls. Tilt anomalies, considerably larger than the rain induced tilts, were recorded around the event of October 31, 1996, coincident with an extraordinary high seismic activity. If this activity reflects internal fracture processes prior to the eruption, the accompanying deformations might partially explain the observed tilt signal.

LOCATION OF THE SOURCE AND SHALLOW VELOCITY MODEL DEDUCED FROM THE EXPLOSION QUAKES RECORDED BY TWO SEISMIC ANTENNAS AT STROMBOLI VOLCANO.

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In the framework of the seismic experiment carried out at Stromboli volcano in September 1997 two seismic antennas (300 m aperture) were set about 1500 m far from the active craters, in two different sites. 24 1 Hz sensors were used for Ginostra array, located in the western part of the island, while 32 4.5 Hz, extended to 1 Hz, were used for Semaforo Labronzo array, located in the northern flank. About 100 explosion quakes, contemporaneously recorded by oth the arrays, were analysed using the zero-lag cross-correlation method. Slowness and back-azimuth measured at the two antennas were used to obtain the location of the source. Velocity dispersion curves were obtained at Ginostra array using single station methods (MFT, PMF). The shallow shear wave velocity model for Ginostra, inferred from these curves has been compared with that obtained for Labronzo site. Results show that the explosion quakes are generated close to the active crater area. The velocity models give useful informations on the first 200 meters, showing in both sites a layered structure with shear wave velocity increasing from 500 m/s at surface up to 1500 m/s at 200 m depth.

PETROLOGICAL TRIGGERS TO VOLCANIC ERUPTIONS: SILICATE-CARBONATE MAGMA UNMIXING

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Field evidence and laboratory experiments on disaggregated mantle xenoliths in volcanics from Southern Italy show that volatile solubility in magmatic systems rapidly changes after two-liquid unmixing. In this model, a steady state process, such as crystal fractionation, drives an alkaline silicate magma to a two liquid immiscible state (silicate-carbonate). If melt segregation is rapid, which is likely due to different physical properties, then continued crystallisation of high temperature silicates from the carbonate melt can cause volatile oversaturation and development of a free vapour phase. Energetic release of the high pressure, vapour-charged system propagates eruption. Silicate crystallisation on, for example, conduit linings fluxed by carbonates results in rapid crystal growth, and may produce megacrysts. We have examined the role of alkalies on phase relations and liquid compositions in the simple carbonate-silicate system between pargasite-calcite. Vesiculation at shallow depths in volcanic eruptions is well understood, and may involve water table interaction. Our results are more applicable to deep pre-vesiculation events which occur at high pressures in the deepest crust of upper mantle and are expected to produce maar-type deposits.

TIME AND SPATIAL CLUSTERING OF ETNEAN SEISMICITY, 1981-1991

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The relations between seismic activity and flank eruptions at Mt Etna (Italy) have been investigated using fractal dimension analysis for the period 1981-1991, characterized by seven major flank eruptions and continued seismicity. The seismic data set can be considered complete from M 2.5, using the completeness test of Tinti and Mulargia (1985). The geometric fractal dimension D is evaluated by the correlation integral method (Grassberger and Procaccia, 1983), which gives weight to the number of elements inside each sampling box. The time and spatial evolution of the temporal fractal dimension D_t, calculated on a 40-seismic-events moving window, indicates a mid-term variation (timescale of years) related to stress conditions within the volcano and a short-term change induced by the approach to a flank eruption. The results are consistent with those from a similar analysis for the period 1874-1913 (De Rubeis et al., 1997). In addition, the spatial clustering of events can be attributed to three structural domains: Mt Etna itself, and the neighbouring Tindari-Giardini Line and the Western Iblean mountains. Such structural associations help distinguish tectonic and magmatic controls on seismicity and eruptions, so also helping to improve long-term assessments of volcanic hazard.

RISK EVALUATION WITH STOCHASTIC MODELS OF LAVA FLOWS

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Numerical models are commonly used for theoretical studies of lava-flow dynamics. Their application requires detailed knowledge of local factors, such as initial eruption conditions and topography. Since most of these factors are poorly constrained ahead of an eruption, such models have limited use for forecasting risk. An alternative approach is to treat a flow as a stochastic rather than deterministic system, so that its progress is determined by a set of guidelines in place of initial and boundary conditions. Flow advance is still governed by standard physical rules but its route is allowed to divert from the path determined by the strict deterministic solution. The probability that a flow takes a given path increases as that path more closely follows the deterministic route. By combining the outcomes of a large number of simulations, the stochastic approach provides a rapid, flexible and reliable means of preparing probabilistic vulnerability maps for a wide range of eruption scenarios.

LANDSCAPE RESPONSE TO AIRFALL DEPOSITS FROM LARGE EXPLOSIVE ERUPTIONS: AN EXAMPLE FROM CAMPANIA, S. ITALY

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The south-eastern sector of the Campanian Plain contains several alluvial fans of volcanoclastic material, located in a limited area bordering hills near the towns of Nola and Palma Campania. Several depositional bodies each form a single alluvial fan. The deposits consist of nearly homogeneous pyroclastics produced during large explosive eruptions from either Somma-Vesuvius or the Phlegrean Fields. U-shaped channels cutting the bodies indicate normal stream activity during intra-eruptive periods. Carbonate-gravel stream deposits followed by volcanoclastic debris-flows and hyperconcentrated flood-flows form the infilling sequence of each channel, often topped by sheet flow deposits. The alluvial bodies could have evolved over periods from months to tens of years, depending of the volume of pyroclastics and climatic conditions. The occurrence of such peculiar alluvial fans results from their location along the main dispersal axis for Phlegrean and Vesuvian fallout deposits, as well as to flat-lying relief in this zone. Understanding these deposits is important for assessing the mid-to-long term possibility of major flooding and lahar generation after large explosive eruptions from the Campanian volcanoes.

GAS CHEMICAL STUDIES AT MERAPI VOLCANO, INDONESIA

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A specially designed, automatic gas-measuring device, consisting of a gas chromatograph, an alphazintillometer and a temperature sensor, was installed at the summit of Merapi in May-June 1997. Over several days, the concentrations of H_2O, CO_2, SO_2 and H_2S were measured every 35 mins and those of ^{222}Rn and ^{220}Rn (Thoron), with fumarole temperature, every 70 mins. The data were sent via radio link to the Merapi Volcano Observatory in Yogyakarta. Gas and fumarole condensates were sampled conventionally and analysed for He- and H- and O-isotopes at the GFZ. The data show a positive correlation between SO_2 and CO_2, but negative correlations between these and H_2O. Gas concentrations pulsed every 3-4 hours, SO_2 and CO_2 increasing and H_2O decreasing, while gas temperature and the ^{220}Rn concentration both increased with increases in gas velocity. Increases in gas pressure associated with larger SO_2 and CO_2 fluxes may have induced rockfalls and related seismicity (Suharno, pers. comm.). The $^3He/^4He$-ratios of $8\text{-}8.8 \times 10^{-6}$ are typical for volcanoes at convergent plate boundaries. H- and O-isotope data from spring water and fumarole condensates indicate a dominance of meteoric over magmatic water. The results suggest that magma formation involves melting of the subducted Australian Plate (containing trapped ocean water). Fluids escaping from ascending magma are diluted by surface water, but their proportion helps constrain estimates of magma volume and may aid forecasts on long-term dome growth.

SE34 Rockmagnetism, palaeomagnetism and environmental magnetism

Convener: Hoffmann, V.

01 New challenges in rockmagnetism, palaeomagnetism and environmental magnetism

Convener: Hoffmann, V.
Co-Convener: Petrovsky, E.

PALAEOENVIRONMENTAL RECORDS IN ARCHAEOLOGICAL PALEOSOLS: MAGNETIC, MOESSBAUER AND PEDOLOGICAL STUDY

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The use of palaeosols as evidence for environmental changes is based on the relationship between soil properties, soil forming processes and soil forming factors. The investigation of more then 50 profiles of palaeosols (buried soils) of archaeological monuments of various age in comparison with recent background soils were carried out. These burial mounds, known as khourgans , were constructed during Bronze Age, Early Iron Age and Middle Ages in steppe belt of Eurasia. A time interval of a hundred years and even less can be reached. The informative soil properties for reconstruction of steppe environment are amounts and profile distributions of humus, carbonate and gypsum, degree of solonetz formation, magnetic susceptibility and iron state (Moessbauer spectroscopy, XRD). Magnetic susceptibility (average weighted value in soil profile) reflects the age of soils. Comparison of soils buried under khourgans suggests the chronology of climatic changes in the region during the late Holocene.

SOIL FORMATION MAGNETIC RECORDS: PROFILE AND AGGREGATE LEVELS.

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Magnetic susceptibility values (MS) and mineralogical composition (XRD and Moessbauer spectroscopy) of clay fraction of barrial (North Caucasus, Russia), subtropical and tropical (Georgia, China) soil profiles developed from loess, marine clay deposits and weathering crusts were under study. In order to investigate the mineral transformation trends on the aggregate level separation of clay fraction in an accordance with strength of particle bindings into 6 parts and their study with a complex of methods has been undertaken. MS is a genetic parameter of soil formation. The character of its profile distribution depends on a combine action of a number of factors and is a specific soil characteristics. Aggregated soil material is characterized by heterogeneity of composition and properties. Loosely aggregated clay from soil horizons is characterized by higher mineral weathering and MS values in comparison with clay from parent material. Its value depends on soil genesis. Tightly aggregated clay contains, as a rule, non-swelling, weaklier weathered layer silicates with higher $Fe^{2+}/(Fe^{2+} + Fe^{3+})$ values, fine dispersed carbonates. Their ·MS values are close for all soils studied and parent material. The specific feature of aggregated material as well as of soil profile is the development and their MS characteristics are the records of this process. The data obtained confirm the genetic origin of soil ·MS properties.

THE NEW PARAMETER FOR MAGNETIC GRANULOMETRY OF ROCKS

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It is well known that sizes of magnetic particles in sediments reflect sedimentation environments. That is why magnetic granulometry is widely used for investigation of the paleogeographical conditions of sedimentation. Theoretical and experimental substantiation of parameter Ii/Is (Ii-unhysteretic magnetization) for determination of domain state and sizes of rock ferrimagnetic particles has been done. The values of Ii/Is may be precisely calculated theoretically for single domain (SD) and multidomain (MD) states. Our studies of artificial samples with different sizes of magnetite grains ranging from large monocrystal MD to PSD and stable SD have shown that changes of parameters Ii/Is, Iri/Is are similar to those of traditional ones - Hc, Irs/Is, Hcr/Hc. The commonly used parameter Iri/Irs for artificial samples is obviously less changable than Iri/Is. It has been shown, that in many cases for natural sediment samples parameters Ii/Is, Iri/Is are more advantageous in determining ferrimagnetic particles sizes as compared to traditional parameters.

NORTH CAUCASUS LOESS:MAGNETIC SUSCEPTIBILITY AND MOESSBAUER STUDY.

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The investigations of magnetic susceptibility (MS) and Fe-state (Moessbauer spectroscopy) of soils in steppe environment and loess-palaeosols sequences of 15 cores in North Caucasus (regions between lats. 44-47 °N and longs 40-46° E) were undertaken. The thickest sequences of loess palaeosols in the Tersko-Kumskoy depression exceed 150 m. For palaeoclimatic reconstruction it is necessary to establish the relationships between state of Fe-compounds in soils of steppe zone and pedoenvironmental conditions .The magnetic susceptibility of modern soils and Fe-state in steppe environment reflect the peculiarities of soil-forming and landscape geochemical processes. Magnetic susceptibility values of palaeosol layers are from 2 to 8 times higher than of the loess. Ratio $Fe^{2+}/(Fe^{2+} + Fe^{3+})$ in loess series is obviously higher than that in the buried palaeosols. This is in agreement with the fact that the palaeosols were formed during warm-humid environment, while loess formation was at a maximum cool, dry climatic periods. The different types of palaeosols, which formed during various geological periods reflect that climate in the region of Tersko-Kumskoy depression (North Caucasus) had undergone several replacements from warm to cold in different extent . On the base of investigations of loess-palaeosol sequences the palaeoclimatic and palaeolandscape reconstruction's during the late Quaternary in North Caucasus could be done.

INTEGRATION OF ROCK MAGNETIC AND ROCK DEFORMATION STUDIES

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The integration of rock magnetism, paleomagnetism and rock deformation studies has provided significant advances in the structural interpretation of deformed terranes in recent years. This is attributed to three main developments that will be illustrated with regional examples. First, Magnetic fabrics show subtle, but consistent anisotropies that can usually be proven to be tectonic. Thus, otherwise concealed strain directions and strain symmetry is known. This helps in kinematic analysis of orogens. Second, paleomagnetic vectors provide unique structural markers that may be deflected by finite strain and flag particular time events and plate tectonic locations during the deformation sequence. Multiple remanence components are even more revealing and can prove progressive folding, tilting, etc. Third, magnetic remanence may be very sensitive to stress in some cases, so that it remagnetises or is deflected by an ephemeral stress regime. This together with some magnetic fabrics this may reveal stress regimes rather than finite strain states and has potential for neotectonic studies.

ANISOTROPY-CONTROLLED THRUSTING OF ARCHEAN LOWER CRUSTAL ROCKS: A ROCK MAGNETIC STUDY AT KAPUSKASING, CANADA

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Magnetic fabrics of the upthrust section of Archean lower crustal rocks at Kapuskasing, Northern Ontario, reveal grain anisotropies with a lineation parallel to the strike of the thrust and a foliation somewhat gentler dipping than the thrust. Thus, the thrust appears to have propagated, controlled by fabric anisotropy, rather than the lineation being associated with the thrust kinematics. The magnetic, and hence petrofabric, foliation in the lower crustal rocks seems to be correlated with the diffuse seismic reflectors. The magnetic fabrics were defined on the basis of both anisotropy of magnetic susceptibility (AMS), dictated largely by crystallographic alignment of paramagnetic mafic silicates, and by anisotropy of anhysteretic remanence (AARM) due to the preferred shape orientation of magnetite. These fabric orientations are almost impossible to determine by conventional petrographic methods due to the granoblastic nature of these high grade metamorphic, lower crustal rocks. Paleomagnetic data show two well-defined magnetizations centred on (058/47 =Normal, **N**) and (037/-44 = Reverse, **R**) for n=106 characteristic directions [ChRM]. Each is at the centre of a small girdle distribution dispersed along the plane of magnetic foliation (AARM). Thus, the paleomagnetic data carry a tectonic imprint that we attribute tentatively to late, partial stress remagnetization. A reconstruction involving destraining and rotating these directions back towards their initial orientation could suggest that they were an initial, nearly vertical antiparallel N-R pair. However, this cannot be proven. We favour different ages for the N and R-components because the R- component may be associated with late hematization near the Ivanhoe Lake Fault. Paleomagnetic tilt corrections may be unnecessary because the most recent tectonic and metamorphic work shows that the thrust slice had almost the same inclination down to the depths where the remanences' reached their blocking temperatures .

TIME-TEMPERATURE RELATIONS FOR PYRRHOTITE AND MAGNETITE: USE IN RECONSTRUCTING BURIAL AND UPLIFT HISTORIES

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Rocks can be partially remagnetized by heating in nature, for example at depth in thick sedimentary or volcanic sequences, or over subcrustal heat sources such as plumes. Because they record both the paleotemperature and the age of remagnetization, such thermoviscous overprints of primary NRM can be used to calculate burial depths and reconstruct uplift histories.

Our method is based on Néel's (1949) theory of thermomagnetization of single-domain grains. It is applicable to thermoviscous overprints carried by any mineral of single-domain size: micron or submicron size pyrrhotite and TM60 grains; most hematites; and magnetites after low-temperature demagnetization (zero-field cycling to liquid N_2 temperature).

Using NRM overprints acquired by two different minerals, pyrrhotite and magnetite, we find that the Milton Monzonite of the Sydney Basin in southeastern Australia was remagnetized about 100 Ma ago during reheating to (165 ± 30) °C for approximately 100 kyr at a depth of (2.3 ± 0.4) km. These limits on burial temperature and depth are more tightly constrained than conventional estimates using coal accessory minerals, fission track annealing, or metamorphic grade.

ASYNCHRONOUS MAGNETIC OVERPRINTS IN THE VISEAN BASIN OF THE SOUTHERN VOSGES (FRANCE) AS A TRACER OF THE APWP OF VARISCAN EUROPE FROM VISEAN UP TO JURASSIC

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Previous paleomagnetic investigations carried out in volcanic, sedimentary and plutonic units from the Visean southern Vosges basin have evidenced polyphased overprinting during Carboniferous-Permian times. Two small areas (4km^2), where strong overprinting was expected, were sampled extensively in order to stress the characteristics of the overprints and eventually to date them. The various investigated rocks consists of basalts, andesites, tuffs and volcanic breccias, in different tectonic attitudes, allowing a fold test. After thermal cleaning, most sites show two or more groups of directions, mostly carried by magnetite, occasionally by hematite. Most groups of directions occur at different sites. About 95% of the directions are syn- and more generally post-tectonic overprints, acquired after the Latest Visean compression phase. The poles of the mean site directions and particularly of the individual directions draw a 15° wide, nearly continuous belt that fits perfectly with the S like APWP of Variscan Europe from the Early Carboniferous to the Jurassic. Due to the great diversity of rocks, to various grain sizes and degree of porosity, to the vicinity or not of mineralized faults, overprinting was not synchronous.
At least two generations of secondary magnetite were observed. The first one is attributed to the green-schist alteration observed at all sites. The corresponding B and A1 poles correlate with the Middle-Late Carboniferous Carboniferous part of the APWP. The second generation of magnetite, (<5µm) appeared in the Late Triassic and the Early Jurassic. The overprints carried by hematite are restricted to the Late Permian.

ANOMALOUS VARIATIONS OF GEOMAGNETIC PALEOINTENSITY WITHIN A SINGLE PLIOCENE ICELANDIC HYALOCLASTIC LAVA FLOW

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A 2m thick Pliocene hyaloclastic lava flow from Southwestern Iceland was sampled in detail along a vertical profile (17 samples). All samples are characterised by a large, univectorial natural remanent magnetization of reverse polarity carried by titanomagnetite. The samples are stable upon heating and most of them provide high quality Arai diagrams. Top and bottom samples yield approximately the same paleointensity, while those recovered from flow center provide magnitudes twice smaller. Several hypothesis are discussed in order to explain this observation.

PALAEOINTENSITY RESULTS USING MICROWAVE DEMAGNETISATION / REMAGNETISATION

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Initial microwave archaeointensity results (Shaw *et al.* 1996, Geophys. J. Int. **124** 241-244) demonstrated that microwave demagnetisation / remagnetisation could be used successfully in a modified Thellier type experiment with no noticeable thermal alteration occurring. We present new results using the same basic technique but including cooling rate corrections and rock magnetic tests for thermal alteration. A significant reduction in the scatter of data points is achieved on the application of the cooling rate correction. Results are presented for ceramics from different geographical areas and for both historic and ancient lavas. The microwave method of obtaining palaeointensities appears highly successful and applicable in all cases.

THEORETICAL MODELS OF MAGNETIC ANISOTROPY TO STRAIN CONSIDERING TRIAXIAL MAGNETIC PARTICLES

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The movements of individual triaxial particles in the Jeffery (1922) model of strained rocks are much more complex than the movements of the spheroidal particles. However, the degree of anisotropy in the magnetic anisotropy to strain models considering multiparticle systems of triaxial magnetic particles shows very similar values to the models considering spheroidal particles. We explain this observation by assuming that even though the movements of individual particles are very different, the multiparticle system as a whole "averages out" in some way the movements and the resulting magnetic anisotropy tensor does not differ very much from the tensor of the model considering spheroids.

NEW DATA ABOUT PETROMAGNETIC CRITERIONS GOLD-BEARING CRUSTAL BASEMENT

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Petromagnetic properties were analysed gold ore-bearing objects of precambrian crustal basement within the limits of Ukrainian shield. Comparative characteristic metallogenic information of rockmagnetic parameters close studied of gold ores has indicated about practical significant connection between gold-bearing and petromagnetic appearance. Parameters of magnetic hardness have correlated best of all with gold-bearing. Interpretation this fact was fulfiled by creation of magnetic-mineralogical models. With that end of view we have detailed studied ferromagnetic minerals of gold ore-forming objects. Supposedly, afore-cited petromagnetic peculiarities gold ore-forming objects have formed ferromagnetic sulfides. Ferromagnetic sulfides are genetic connection with process formation gold ore. We have reason to suppose that fixating petromagnetic peculiarities have universal information in relation to metallizing process of crustal basement of Ukrainian shield.

THERMAL BEHAVIOUR OF THE FERROMAGNETIC FRACTION ALONG THE LOESS/PALAEOSOIL SECTION IN NE BULGARIA - A HINT FOR PALAEOCLIMATIC CONDITIONS DURING SOIL FORMATION?

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As a part of rock-magnetic study of a 34-m thick loess/palaeosoil section in NE Bulgaria, thermomagnetic analyses of 75 samples were carried out. Three different types of behaviour are commonly recognised: 1) recent soil So shows maghemite presence with Tc of 350°C, followed by an appearance of new magnetic phase, causing a 7-8-fold increase in magnetisation upon cooling; 2) general characteristics of all unweathered loess units are: convex up Jsi(T) curves with single Tc of 600°C; 3) palaeosoil samples exhibit almost reversible behaviour, with heating curve, characterised by the presence of two linear parts - up to 200°C and 200-600°C. Using also rock-magnetic parameters as X, Hc, Xfd%, the following scheme of subsequent processes, which determine the magnetic signature along the section studied, is considered: 1)"in situ" chemical weathering of the loess material, providing initial Fe supply for Fe_3O_4 authigenesis; 2) influence of different geochemical processes in soils developed on loess as a parent material (chernozems, grey-, dark-grey forest soils). A link between soil chemistry, palaeoclimatic factors, magnetic enhancement processes and magnetic grain-size distribution is proposed.

TEMPERATURE VARIATIONS IN DOMAIN STATE OF MAGNETITE-BEARING VOLCANIC ROCKS AS REVEALED BY HYSTERESIS MEASUREMENTS

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Magnetic hysteresis loops for magnetite-bearing volcanic rocks of different origin and age have been measured at temperatures ranging from 77 K to 873 K. Below and at room temperature hysteresis parameters for all samples are in PSD range. Moreover, this PSD state remains stable up to 750-800 K depending on a sample. Between 250 K and about 780-800 K coercive force shows just slightly faster decrease with temperature than saturation magnetization, compatible with largely magnetostrictive control of coercivity. Above 780-800 K coercive force exhibits much slower decrease with temperature, which indicates that the transition from PSD into SD state occurs. Since in most samples over 70 per cent of TRM is blocked above 5000C, and nucleation of new domain walls in weak fields is strongly inhibited, TRM is likely to be initially acquired through a SD-like mechanism. At further cooling this high-temperature SD state becomes metastable, and, on applying magnetic fields at room T or on moderate heating, can easily evolve into a non-SD state with significantly lower remanence. Such process would result in that hysteresis and af demagnetization characteristics enter the PSD range, and a demagnetization of TRM at temperatures lower than true blocking temperatures.

The magnetic signature of pyrrhotite bearing metasedimentary rocks

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Phyrrotite bearing rocks are known to produce magnetic anomaly patterns which often differ in a characteristic way from those observed over rocks containing magnetite. Thus it is possible to use the magnetic signature for a first and rather sure identification of certain rocks types. They are mostly metamorphic sediments of argiliceous or graywacke type in which graphite may be closely associated with the sulphide mineral. In Sweden there are several localities where these pyrrhotite bearing rocks occur. One of them is situated to the south east of the Skellefte ore province, near Robertsfors. Here steeply dipping metasedimentary rocks cover almost 4 map sheets (10 000 km2). The anomaly map shows a narrow-spaced but very consistently banded pattern. The magnetic properties are characterised by high to very high Koenigsberger values. In order to elucidate the petrofysics and geology of a rock unit producing this magnetic signature a detailed study was carried out in an area of high, positive magnetic amplitude. The magnetic total field and the vertical gradient were measured along a profile 114 meters in length. Sampling for petrofysical measurements (Density, Natural Remanent Magnetisation NRM, Magnetic Susceptibility Anisotropy AMS) was carried out at 26 points along the profile by drilling. The mineralogy was examined in four samples. The results show that pyrrhotite is the principal - probably the only - magnetic phase and its NRM dominates the magnetic properties ($5<Q<500$). The orientation of NRM is not consistent along the profile which may be one of the causes to the strongly varying vertical gradients. However, a certain affinity to the largest principal axes of the susceptibility anisotropy tensor is observed. AMS is strongly bound to the rock texture. Within two shear zones the magnetic texture is highly disturbed.

A NEW METHOD OF CALCULATING DEPTH DISTRIBUTION OF ROCK MAGNETIZATION

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The calculations are based on the results of experimental studies of the remanent magnetization(I_r) and magnetic susceptibility($æ$) of eruptive rocks at high hydrostatic pressure(P) and temperature(T)including their simultaneous (PT) effect. The PT experiments were made on specialized equipments according to model programs of depth distribution of P (to 300 MPa) and T (to 300°C) for specific geologic bodies. The I_r changes were immediately calculated from experimental PT data. The behaviour of æ was calculated from experimental data of radial P and T effect for respective depths. The studies showed that the contribution of I_r to the total one is essential in the near-surface crustal beds. At great depths the I_r effect decreases and the total magnetization will be mainly determined by the inductive component.

CAMBRO-ORDOVICIAN PALAEOMAGNETIC RESULTS FROM BORNHOLM (DENMARK), AND IMPLICATIONS FOR THE DRIFT AND ROTATION OF BALTICA.

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From the Danish island Bornholm 191 sediment cores from three Lower Cambrian formations (Nexø Sandstone, Balka Sandstone, Grønne Skifre) and limestones from the Lower Ordovician Komstad Kalk Fm have been palaeomagnetically analysed by PCA Vector Lines, Subtracted vectors and Great-circle tracks. Using Spherical Density plots, 5 to 6 clusters of magnetic components were obtained by each method (A_L-F_L, A_S-E_S, A_G-E_G) mostly confirming each other, although not all clusters are significant at 95%.

The directions D_S, E_S, E_L, F_L are not yet known from Baltica in the Phanerozoic. Considering their statistical and palaeomagnetic significance, their high blocking temperatures and their bi-modal polarity pattern, we suggest that these directions may represent both near-primary and secondary magnetisations of Cambrian age, ordered in a yet unknown sequence. Their common features are 1) shallow inclinations, suggesting a sub-tropical position of Baltica when these components were acquired, and 2) significant changes about 90° of declination in the SE/NW quadrants, indicating quite fast block rotations of Baltica at that time, provided that our age estimates are correct.

MAGNETIC CHARACTERIZATION OF MANGANESE OXIDES FROM THE TAMBAO LATERITIC ORE DEPOSIT (BURKINA-FASO)

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A 120m depth core was sampled in the lateritic manganese-ore deposit of Tambao (Burkina-Faso), which derived from a birrimian hausmannite-rich metacarbonate serie. The iron-manganese minerals associations were characterized using X-Ray diffraction, optical microscopy, chemical analyses.

With regard to the Fe content ([Fe]< 5 wt% in the whole profile), low-field susceptibilities ($0.5<\chi< 100.10^{-6}m^3/kg$) indicates that Mn (15<[Mn]<80 wt%) must take part to magnetic minerals in the parent rocks as well as in the overlying weathered units.

On one hand, and among other rock magnetic parameters, low-field thermomagnetic curves (from -190 to 700°C) were then tested to characterize these Mn oxides from their magnetic transitions as well as their thermochemical tranformations under heating. On the other hand, magnetic properties were used to discrimate between inheritance and possible neoformation processes of Mn/Fe-oxides. These latter processes were actually suggested by the fact that the great variations of low-field susceptibility observed in the parent rocks are erased in the weathered units.

ORIGIN OF COERCIVITY IN MULTIDOMAIN MAGNETITE

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The temperature dependence, as well as the magnitude, of coercivity is different for nucleation and various types of defect pinning. Nucleation leads to a coercivity $H_c \propto K/M_s$, where K is the predominant anisotropy constant and M_s is saturation magnetization. Wall pinning due to stress fields of dislocations or planar defects gives $H_c \propto \lambda/M_s$, where λ is magnetostriction constant.

We have measured H_c and M_s as a function of temperature, T, in order to understand the origin of coercivity in a mm size single crystal of magnetite using a Micro VSM at the IRM, University of Minnesota. The experimental $H_c(T)$ data vary approximately as $\lambda_{111}(T)/M_s(T)$, indicating that the coercivity in the present multidomain crystal is mainly magnetoelastic.

However, there is a small difference between the experimental data and the theoretical curves, which probably arises in the following way. The theory leading to the $\lambda_{111}(T)/M_s(T)$ dependence of H_c is for a single dislocation and a constant wall width w. Most theories of defect controlled microcoercivity predict that $h_c(T)$ depends on $w^m(T)$, where m depends on the number and arrangement of defects. The calculated curve, $H_c(T) \propto \lambda_{111}(T)w^{0.5}(T)/M_s(T)$, agrees very well with the experimental $H_c(T)$ data. This agreement indicates that the coercivity in multidomain magnetite is controlled mainly by crystal defects.

A ROCK MAGNETIC STUDY OF A REGIONAL DEFORMATION ZONE IN THE FENNOSCANDIAN SHIELD

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The Storsjön-Edsbyn Deformation Zone (SEDZ) is a 200 km long and 10-30 km wide zone, which strikes NNW-SSE through the central parts of the Fennoscandian Shield. It separates a 1.7 Ga old granite in the west from a 1.8 Ga old granite and a 1.9 Ga old granodiorite in the east. By the use of AMS, susceptibility versus temperature measurements, thermal and AF demagnetisation, this study was performed to make a rock magnetic characterisation of the SEDZ and to test an existing tectonic model. Samples were collected mainly along two profiles crossing the zone, and signs of deformation existed up to 18 km from its centre. The AMS lineation rotates from vertical at the centre of the zone to sub horizontal at distance, indicating transpression. There are examples of good correlation between the degree of AMS and the volume susceptibility. Two unaltered dolerite sills cutting the SEDZ have a paleomagnetic age of c. 1250 Ma, which post dates its movements. A pre existing E-W striking and moderately dipping regional metamorphic pattern is partly overprinted by the SEDZ. The degree of AMS and the volume susceptibility generally decreases when approaching the centre of the zone, probably due to a destruction of magnetite.

LAKE PARINGA: A CATCHMENT STUDY USING MAGNETIC TECHNIQUES

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Mineral magnetic measurements were carried out on sources and sediments from the Lake Paringa catchment, South Island, New Zealand. The Alpine Fault runs through the catchment area and rocks of different lithology and age outcrop on either side of it. The measurements indicate the sources from the east of the Alpine Fault (schist bedrock) are magnetically soft and magnetite rich, whereas the sources from the west of the fault (greywacke bedrock) are magnetically hard and haematite/goethite rich. Comparison between the sources and sediments indicate post-depositional chemical alteration, namely the formation of greigite has occcured within the lake. A quantitative unmixing technique using only IRM data has been developed. It is possible to quantitatively unmix the sediments in terms of their sources and authigenic greigite, thus getting an indication of the varying contributions from east and west of the Alpine Fault to the different areas within the u-shaped lake.

INCREASED NRM INTENSITY DUE TO SEISMIC VIBRATION

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Sediments that have been subjected to ground acceleration (earthquakes) are found to have achieved an increased magnetization. This is because the grains have got a second chanse to orient in enlinment with the existing magnetic field. 20-15 years ago, we noted that there was a very sharp intensity peak in the sediment laid down at about 10,000 radiocarbon years ago or at the glacial varve known as -1073 in De Geer's varve chronology. Later, it was understood that this peak coincided with an exceptionally large earthquake in Stockholm-Mariefred area in Sweden (Mörner, 1981, 1996). The glacial varves are of special interest because they clearly record ground vibration. We have notet that the NRM intensity (and polarity enlignment) is significantly increased in those horizons that also record vibrated structures. In the case of paleoseismically induced liquefaction, we are using the magnetic signals as a test of the fluidization of the sediments. Contrary to tectonized convolution structures (where the magnetixation is inverted), liquefied convolution structures show more or less "normal" polarization with respect to the horizontally bedded layers below and above.

TEMPORAL SPECTRA OF SV

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Geomagnetic field is generated in the liquid core of the Earth. As a consequence of the vacuum boundary conditions at the core-mantle surface only the normal component of the field propagates through the surface into the mantle. Then, at the Earth's surface we have 3-D magnetic field which can be measured. As a conclusion, because of the specific of paleo- and archeomagnetic measurements we have at our disposal the different time series for the analysis such a as the follows: X-, Y-, Z-components, the intensity F, the inclination, I and declination, D. It is not clear *apriory* that the temporal spectra of these quantities, as well as the geomagnetic field sources itself, are the same. This idea is confirmed by some experimental date (see e.g. [1]). Here we propose some numerical models of SV to answer this question. We take for the models the follows: the model of oscillating, wobbling dipole and MAC-waves. It is shown that the result depends drastically on the level of the stable geomagnetic field what can be related e.g. to the time intervals without reversals.

References

1. Creer, K.M., Thouveny, N., Blunk, I., *Climatic and geomagnetic influences on the Lac du Bouchet paleomagnetic SV record through the last 111 000 years* Physics of the Earth and Planetary Interiors. 1990. V.64. P.314.

THE PALEOCLIMATIC SIGNIFICANCE OF ROCK MAGNETIC PROFILES FROM LOESS-SOIL DEPOSITS IN SW GERMANY

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Loess-Paleosol sequences in SW Germany consist of alternating loess and paleosol layers with intercalated mixed zones and redeposited humus zones with varying layer thicknesses. A rock magnetic study of several profiles comprising the last two glacial cycles has been carried out. The damming wetness that is formed in local synclines often causes the dilution of magnetic minerals of the paleosols and leads to a significant decrease of the susceptibility (k) signal. This is confirmed by low values of k, NRM and frequency dependent k that illustrate a lack of enrichment of superparamagnetic particles in these sections. IRM acquisition and thermal demagnetisation of SIRM indicate an increasing amount of hematite. Despite these difficulties the magnetic susceptibility of samples that have been collected at parallel sections at distances of 10 cm, 10m, 100m and 10 km can be correlated. From this point of view we suppose that despite the occurence of chemical alterations in the soil horizons magnetic susceptibility can be used as a proxy parameter for paleoclimatic investigations in this area.

APPLICATION OF COMPLEX MAGNETIC WELL LOGGING FOR THE STUDY OF TRAPS IN YAKUTIA DIAMOND BEARING PROVINCE

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Traps are the main hindrance for geophysical methods which are used in the search for kimberlite pipes in Yakutia diamond bearing province. A study of their properties and structural features increases the reliability of geophysical anomalies interpretation. On the other hand on the base of studying of the traps it is possible to make conclusions about structural features of sedimentary rocks containing and overlaying the kimberlite pipes. Trap sills repeat structures of sedimentary rocks, in which they were intruded, but as they are more contrast in properties it is more simple to study them by geophysical methods. For studying traps magnetic properties a high-precision WKMK-1 complex magnetic well logging instrumentation, intended for simultaneous measurements of magnetic susceptibility χ with accuracy of $1\cdot10^{-5}$ SI and magnetic field vertical component ΔZ with accuracy of 5 nT was created. The complex magnetic well logging is used for determination of a geological nature of magnetic anomalies, differentiation and correlation of the wells sections, traps mapping in χ, signs of magnetization and values of Q_Z (vertical components of a remanent and induced magnetization ratio), investigation of kimberlite pipes of a complicated structure (multiphase, with various types of kimberlite, overlaid and intruded by traps of different signs and values of magnetization), determination of χ and Q_Z parameters of rocks for creation authentic models of research objects.

METACARBONATES FROM THE LESSER HIMALAYA: DO THEY HAVE POTENTIAL FOR PALAEOMAGNETIC STUDIES?

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Lesser Himalayan units close to the Main Central Thrust contain valuable information for studying Himalayan mountain building. However, only medium grade metamorphic rocks are existing there. A pilot study on metacarbonates from India and Nepal support the suitability of these rocks for further palaeomagnetic investigations. During thermal demagnetization the NRM is mainly unblocked in a narrow temperature range around 300°C. The remanence is likely to be carried by pyrrhotite acquired as a secondary TRM during regional cooling dated around 20 Ma. For low differential stress only brittle deformation is expected below 300°C in carbonate rocks. Remanences within sites demonstrate that indeed a consistent directional behaviour occurs. For the Garwhal Himalaya (India), well grouped mean site directions are obtained within an area of about 50 km (6 sites, 45 specimens, k=19.5). In Central Nepal, a softer AF demagnetization behaviour is observed, and remanence directions are more scattered within sites and between different localities.

THE STUDY OF COMPOSITION AND SIZE OF DISINTERGRATION STRUCTURES OF TITANOMAGNETITE USING THERMOMAGNETIC ANALYSIS

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Original composition of the magnetite-ulvoespinel solid solution and size of disintegration structures of this series can be determined by analysing thermomagnetic saturation curves of the first and second heatings. The method is based on the comparison of calculated curves with experimental those. Used for calculating the curves which model titanomagnetite's homogenizing while heating a sample was the principle that titanomagnetite's homogenizing can be considered to be a process of interdiffusion of titanium and iron ions.

The results of the Western Yakutia (Russia) trap studies display good correlation with those of microsound analysis.

ARTIFICIAL MAGNETITE-BEARING SEDIMENTS WITH DIFFERENT INITIAL MAGNETIC STATES OF MAGNETIC PARTICLES: FIELD DEPENDENCIES OF THEIR ORIENTATIONAL MAGNETIZATION

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Eight sets of sediments have been deposited in horizontal magnetic fields taken within the interval 0<H<48 Oe. Each set consisted of eight sediments with magnetic particles in a fixed initial magnetic state. As the initial magnetic states were chosen those with TRMs preliminarily induced in the magnetic fields h in the range 0-300 Oe. The magnetic grains were submicron magnetite particles extracted from crushed iron ore deposit of Kostomuksha (Karelia). Their concentration in the sediments was taken about 0.7 weight per cent. Analysis of the obtained experimental results allowed to conclude that the ordinary Langevin interpretation cannot give a real picture of a deposition process. It was shown that all the complex of the sediment field dependencies DRM(H,h) had to be considered as a number of the bimodal Langevin processes: DRM(H) = I(1)7 Lang (H/Hchaot1) + I(2)7Lang (H/Hchaot2), where I(1) and I(2) are limit magnetizations of modes, Hchaot1 and Hchaot2 - respective chaotization parameters (Hchaot1 >> Hchaot2). The joint analysis of data on DRM(H,h) dependencies and TRM acquisition in Kostomuksha magnetic particles had allowed to characterize the magnetic microstructure of magnetite particles and to formulate some elements of the phenomenological theory of TRM process in them.

UNUSUAL LOW-TEMPERATURE HYSTERESIS AND THERMOMAGNETIC BEHAVIOUR OF BASALTS FROM TENERIFE

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Low temperature magnetic techniques provide useful methods to detect the presence of certain iron oxides, iron carbonates and iron sulphides. In order to further elucidate the properties of natural magnetic minerals we have performed (i) thermal demagnetisation of remanences grown by cooling to 5K in a 1T field (ii) low-temperature $M_s - T$ and $\chi - T$ experiments and (iii) hysteresis measurements at temperature down to 5K using a magnetic susceptometer ($MPMS_2$) with a SQUID detector. Very unusual assymetrical, double wasp waisted hysteresis loops have been found in basalts from Tenerife where they are cooled to low temperatures.

PERU BASIN SEDIMENTS: CLUES AS TO ALTERATIONS TO THE NRM

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R/V Sonne cruises 78 (1992) and 106 (1996) were designed to assess the range of geochemical conditions of pelagic Peru Basin sediments. We present the paleo- and rock-magnetic results obtained from Site 152/261 (7 04'S / 88 28'W in 4170m water depth) as a function of the Fe-oxidation state downhole to a depth of 8 m. Magnetostratigraphic results are straightforward and polarity changes of the geomagnetic field can be traced to top of the Olduvai. A normal overprint with directions corresponding to the Brunhes Chron characterizes the NRM from the Brunhes/Matuyama boundary (at 3.7 m) downhole. The overprint ceases at 5.4 m. This coincides with the lower boundary of an interval starting at 2.6 m (modern Fe-redox boundary) where there is a large increase in Fe^{2+} (Moessbauer spectoscropy). Clues as to the diagenetic origin of parts of the NRM come from a multi-parameter approach using standard rock-magnetic measurements (ARM, IRM, susceptibility). Alteration to the magnetic signal as a consequence of the Fe-redox boundary can be shown using multivariate statistical techniques (fuzzy c-means clustering and non-linear mapping). Low-temperature measurements (MPMS, 20K - 300 K) unravel the link between the interval of increased Fe^{2+} and the concomitant NRM overprint. Appearance and disappearance of (re-precipitated) very fine grained magnetite is exactly correlative with this interval.

KINEMATIC RELATIONS BETWEEN MAGNETIC (AMS, AARM) AND TECTONIC FABRICS FOR THE NIEMCZA FAULT ZONE, SUDETES FORELAND, SW POLAND

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Anisotropy of magnetic susceptibility (AMS) and anisotropy of anhysteretic remanence (AARM) studies are being performed for 17 sites with mylonites, gneisses, gabbro, serpentinite and granitoids within the Niemcza Fault Zone located in the Sudetic foreland in SW Poland. Previous petrographic, structural and microtectonic studies in sites within the zone support the process of mylonitization of the Sowie Mountains gneisses in the strike-slip sinistral shear zone developed along the eastern margin of the Sowie Mountains block. The relations between magnetic foliations (AMS kmin and AARM kmin axes) and tectonic foliation planes as well as magnetic vs tectonic lination recorded on sample and site scale. The preliminary results indicate that they may be used as the kinematic indicators of noncoaxial deformation with dominant sinistral shear component within the area. The regional variability of the magnetic fabric (both direction and anisotropy parameters) will be also correlated with the postulated Sowie Mountains gneissic origin of the Niemcza zone mylonites. The relation of the magnetic fabric of the gabbro, serpentinite and granitic bodies with those of the mylonites is also tested.

SE34 Rockmagnetism, palaeomagnetism and environmental magnetism

Convener: Hoffmann, V.

02 Past and present geomagnetic field

Convener: Prevot, M.
Co-Conveners: Love, J.J.; Schnepp, E.

NUMERICAL MODELS OF THE GEODYNAMO

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Understanding the geodynamo that operates in the Earth's fluid outer core and which maintains the Earth's magnetic field against Ohmic decay is among the most challenging problems in Earth science. Recently, in large part due to the work of Glatzmaier and Roberts, numerical modelling has shown great promise as a means to understand the geodynamo.
However, despite these encouraging results it is increasingly becoming clear that numerical geodynamo models do not yet adequately describe the geodynamo process. In particular, the models do not operate in the same parameter regime as the geodynamo and, furthermore, include assumptions that are adopted for reasons of numerical expediency rather than geophysical reality.
Here we contrast two different numerical models of the geodynamo, and find that although both generate predominantly dipolar fields, in other words fields not unlike the Earth's, there are considerable differences in how the models operate. We demonstrate that these differences arise from the manner in which the viscous boundary layers are treated. If viscous effects play a sufficiently strong role (much stronger than in the Earth's core), we can obtain solutions similar to those of Glatzmaier and Roberts. However, we find evidence that solutions in this regime are better described as Ekman or weak-field states in which the magnetic field strength is controlled by viscous effects.

On the age calibration of the Geomagnetic Polarity Time Scale

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Our knowledge on the age of undated events, such as most of the reversals of the geomagnetic field, is not null if a time-order relationship can be found between these events. The knowledge on a such time-ordered sequence can be formalized by using the non-informative (uniform) prior probability density distributions for the ages of undated events and the Bayes' theorem to introduce the time-order relationship condition. We show that the posterior density probability distributions of the ages of events of unknown age are given by various forms of Euler's beta distribution. These distributions yield an estimate of the probability for an event of unknown age to occur in a given age interval.

We use this method to build appropriate probabilistic representations of our actual knowledge on the dating of the magnetic polarity reversals during the Upper Cretaceous and the Cenozoic taking into account the uncertainties arising from the non-regularity of spreading rates in the South Atlantic ocean and from the quality of a few calibration points. Both types of uncertainties generate ambiguities on the age of the magnetic reversals which are far to be negligible.

Finally as a general application of our method, we have carried out computations for the magnetic polarity sequence over the last 75 Myr.

GEOMAGNETIC VARIATIONS IN EASTERN EUROPE DURING THE LAST 7500 YEARS

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Generalization of the available observatory, palaeomagnetic (lacustrine sediments) and archaeomagnetic measurements on the territory of East European Russia indicated 1) good correlation between observatory and palaeomagnetic data and 2) scarcity and scattering of archaeomagnetic data. There have been conducted palaeomagnetic investigations of modern sediments of two lakes. Radiocarbon dating and extensive statistics (4 to 5 columns from each lake) permitted to draw master curve for the last 3500-4500 years. Variations with periods of several hundreds years have been marked out and correlated. PSV of the last 7500-8000 years have been analysed. Acquired data have been compared with West European data. The West Drift hypothesis is presently being considered.

PALAEOSECULARVARIATIONS AS RECORDED IN SEDIMENTS OF ITALIAN CRATER LAKES

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Palaeomagnetic records of the geomagnetic secular variation back to ca. 32.000 and ca. 100.000 have been obtained from two sediment cores from Lago di Mezzano and one core from Lago Grande di Monticchio. The investigation comprises magnetic susceptibility, NRM and ARM. Intra lake correlation was carried out by using the data of continuous high resolution susceptibility measurements. NRM and ARM of all 4100 subsamples were measured with a fully automated cryogenic magnetometer including AF-demagnetization in 11 steps up to 100 mT. The ChRM-direction records were stacked and transformed to a time scale to perform inter lake comparison, also using palaeosecularvariation records from Lac de Joux and Lac de Bouchet. For estimating the palaeointensities the NRM-intensity of the sediment after demagnetization at 20 mT was normalisized, using the results of the ARM-measurements. The results agree with the result from the Mediterranean Sea. The calculated ratio of ARM_{sus} /susceptibilty from the sediments of Lago di Mezzano reflects very clearly the changes in the composition of the sedimentary input, controlled by global climatic changes.

GEOMAGNETIC PALEOSECULAR VARIATION IN CROZET ISLANDS (INDIAN OCEAN) ABOUT ONE MILLION YEARS AGO

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The Possession Island of the Crozet Archipelago consists of volcanic units which erupted mainly between 1.3 and 0.5 Ma. A paleomagnetic sampling was carried out along several sections distributed near the Northern, Eastern and South-Eastern coasts. A total of 37 independent flows were sampled (322 samples). For each flow, a precisely defined characteristic remanence direction was generally found after alternating or thermal progressive cleaning. The magnetostratigraphy of the lava pile is quite simple, with reversed (presumably Matuyama) rocks in the lower part and normal (presumably Bruhnes) units in the upper part. In contrast to Watkins et al. (1972), we do not found any intermediate direction lying in between these two magnetozones. The amplitude of paleosecular variation is estimated from between-flows directional scatter using a recently proposed vectorial model of geomagnetic fluctuations (Camps and Prévot, 1996).

WHAT CAN WE LEARN WITH EXPERIMENTAL DYNAMOS?

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Laboratory modeling of a homogeneous liquid dynamo is difficult. The magnetic Reynolds number ($\mu_0 \sigma UL$) imposes to use a few cubic meters of liquid sodium to enable to observe magnetic self induction in the laboratory. Experimental constraints and differents ideas have led to a few independant research programs : Riga, Karlsruhe, Atlanta, Madison, Cadarache, Lyon, Grenoble... I will review the different projects and try to give their goals and philosophy. I will discuss how good these experiments are for geodynamo modelling and will compare them to numerical simulations. These experiments may give us a physical insight of the fluid mechanics of conductive liquid in a magnetic field.

GEOMAGNETIC EXCURSIONS IN THE DEPOSITS OF THE DENISOVA CAVE (GORNY ALTAI)

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I have performed paleomagnetic investigation of the Denisov cave in Gorny Altai. The sedimentary deposits of the Main hall of the cave have been studied. 200 oriented sample-cubes have picked out from layers 9, 21 and 22 of the main hall of the cave deposits. All investigated samples have been tested by temporary magnetic cleaning and thermal demagnetization at 200 C. As a result of this cleaning the viscous remanent magnetization, which portion forms 20-30practically dont change direction NRM, but slightly decrease its value. As a result of perfomed experiments, the paleomagnetic column was obtained, which was constructed according to the average values of declination and inclination. In this columb on the background of normal polarity (Brunhes chron), peculiar to the Middle Pleistocene, two of reversed polarity horizons in upper and in lower parts of layer 22 have been revealed. Two dates RTL there are for layer 22: in the lower part of the layer - 282 (51 ka (RTL-548); in the upper part of the layer - 225(45 ka (PTL-547). These horizon are identify with geomagnetic excursions. The conjugate analysis of paleomagnetic, thermolumiscence and palinological data allows to correlate the chosen excursion of Biwa I - the upper part of layer 22 and of Biwa II - the lower part of layer 22.

TRANSITIONAL FIELD PALEOINTENSITY FROM TWO ICELANDIC PLIOCENE MAGNETIC POLARITY REVERSALS

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We carried out a rock-magnetic and paleomagnetic study on some Southwest Icelandic volcanic rocks recording the R_3 - N_3 and R_5 - N_5 magnetic polarity reversals. In total 124 lava units and 4 baked sediments (768 oriented cores) were studied. Standard thermal or alternating field cleaning, viscosity index measurements, susceptibility versus temperature experiments under vacuum and continuous thermal demagnetization of PTRMs were performed in order to determine the primary paleomagnetic component and to select the most suitable samples for Thellier paleointensity experiments. The reverse and normal flows yield paleostrengths , close to the present field intensity. Some successful determinations from intermediate flows suggest that the paleofield was reduced significantly during both the R_3 - N_3 and the R_5 - N_5 polarity transitions.

STATIONARY GEOMAGNETIC FIELD OF THE MATUYAMA CHRON AND JARAMILLO SUBCHRON

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We studied the Matuyama chron and Jaramillo subchron in sediments of West Turkmenia. Each of 150 samples (profile 1) distributed over the entire interval corresponds to ca. 2.5 ky interval in the Matuyama chron and to ca. 1.2 ky in the Jaramillo subchron. A sample-by-sample procedure was used for two selected section intervals (profile 2). The first selected interval covers about 25 ky of the Matuyama chron, each of 255 samples corresponding to ca. 100 y. The second interval encompasses about 12 ky of the Jaramillo subchron, and each of 237 samples corresponds to about 50 y. Five specimens per sample were thermally demagnetized. Mean directions of a characteristic component of magnetization are D°=187, I°=-56 and D°=179, I°=-57 for profiles 1 and 2, respectively, of the Matuyama chron, and D°=349, I°=58 and D°=356, I°=60, for the same profiles of the Jaramillo subchron. We identified the only geomagnetic anomaly about 0.5 ky in duration within the Jaramillo subchron. As paleofield intensity, we used NRM/ARM ratio in the 300°-500°C window. Observed periods of declination, inclination and field intensity range from 0.5 ky to 125 ky in the Matuyama chron and from 0.25 ky to 17 ky in the Jaramillo subchron.
This study was supported by grants from International Science Foundation and Russian Foundation of Fundamental Studies.

CHARACTERISTICS OF THE EARTH'S MAGNETIC FIELD WHICH NEED TO BE EXPLAINED BY ANY MODEL OF SECULAR VARIATION.

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Much work has recently been done on characterizing the Earth's magnetic field for use in developing models of the secular variation. The most important of these are the angular standard deviation of the field (or the equivalent virtual geomagnetic poles, or VGPs) as a function of observation latitude, and the scatter of intensity, also as a function of latitude. No formal scheme has been suggested for dividing the field up into "usual" behavior as contrasted with behavior expected during a reversal. Any subdivision into results which give low latitude as contrasted with high latitude VGPs does not hold up when seriously considered. Modern data suggest that even if all results are considered, the VGP scatter increases as a function of observation latitude. These and other results will be discussed.

POLARITY REVERSAL, RECORDED IN DACITIC VOLCANIC ROCKS FROM THE DAMBALUK VOLCANO, EAST RHODOPE MOUNTAINS, BULGARIA

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Anomalous positive, positive and negative directions were recorded in two sites in dacitic effusive rocks from the Tertiary Dambaluk volcano, Bulgaria. The samples come from flow textured lavas and lava breccias, and according to saturation remanence thermal curves, contain magnetite, TM45 and some haematite. High degrees of anisotropy of remanence (1.1<P<2.3) do not explain the origin of the anomalous positive directions. Thellier experiments were unsuccessful as both low and high-temperature cleanings were unable to remove a positive (probably thermal) overprint in one of the sites. Subsequent modified double heating Shaw experiments revealed the scatter in the directions is accompanied by a similar scatter in the palaeointensities, ranging from 5 to 61μT. It is suggested that these dacitic rocks have been extruded during a protracted period of time and have recorded both directional and intensity changes in the geomagnetic field during a polarity transition in the Lower Oligocene.

SOME GEOMAGNETIC FIELD FEATURES IN $\alpha\omega$-MODELS

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Numerical simulations of axisymmetrical $\alpha\omega$-dynamo models without inner core as well with it are considered. We compare some of the wellknown in geomagnetism characteristics of geomagnetic field such as spatial spectrum, reversals, dispersion of the direction of geomagnetic field, bias factor, wave propagation direction, archeo- and paleo- secular variations with the results of this modeling. We observe some different regimes of geomagnetic field generation which can respond to the epochs of the frequent reversals as well as the complete absence of it. The last regime can be obtained by the two different ways: one can increase the dynamo-number $\mathcal{D}$ [1] in the models with the inner core. The solution with the pole-equator wave propagation has been obtained in [2] for the other sign of $\mathcal{D}$. We discuss a link between these results.

References

1. Hollerbach, R., Jones, C.A., *Influence of the Earth's inner core on reversals.* Nature, 1993, V.365. P.541.
2. Anufrief, A.P., Reshetnyak, M.Yu., Sokoloff, D.D., Hejda, P., *Evolution of geomagnetic field in the model of $\alpha\omega$-dynamo.* Geomagnetism and Aeronomy, 1997, V.37, N2, P.91.

CLIMATIC INFLUENCE ON INDEPENDENTLY DERIVED GEOMAGNETIC PALEOINTENSITY STACKS

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The coherence of two independently determined geomagnetic paleointensity stacks for the last 200 thousand year could validate the use of sedimentary cores, either the conventional way [*Guyodo and Valet*, 1996] or by inverting the cosmogenic ^{10}Be production rate [*Frank et al.*, 1997]. Both compilations use mainly climatically controlled oxygen isotope records to date and synchronize the sedimentary records, while this very curve has several coherent features with the supposedly pure geomagnetic quantities. Secular variations in ^{10}Be values caused by climatically induced changes in deep-water flow are expected in most of the cores in the beryllium stack. Moreover, conventionally determined relative paleointensity records show correspondence with climatic features, which is explained by an inadequacy in the normalization techniques. Thus, it is possible that the extraction of pure paleointensity from the sediments has not been accomplished.

REFERENCES

Y. Guyodo and J.-P. Valet, *Earth Planet. Sci. Lett.*, **143**, 23–36, 1996.
M. Frank *et al.*, *Earth Planet. Sci. Lett.*, **149**, 121–129, 1997.

OBSERVATION OF FIELD SYSTEMATICS DURING THE MATUYAMA-BRUNHES REVERSAL AND THE POSSIBLE ROLE OF ELECTRICAL CONDUCTIVITY WITHIN D"

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A thick sequence of Tahitian lavas records the Matuyama-Brunhes (M/B) polarity reversal in detail. The section thus far sampled contains only transitional directions with *VGPs* that continuously migrate between 30°S and 60°N latitudes. Yet, a significant portion of the sequence records paleodirections associated with *VGPs* found off the west coast of Australia, forming a well-defined cluster that overlaps that reported by Chauvin et al. (1990) at a distant Tahitian site. Thus, the two datasets are dominated by *VGPs* within the Australasian cluster patch, consistent with detailed M/B findings from the Pacific Hemisphere: Japanese marine sediments, Chinese loess, and Chilean lavas. We argue that M/B field behavior within this hemisphere was dominated by at least one long-lived field configuration caused by a concentrated patch of vertically-directed magnetic flux emanating from the core near western Australia. Such a flux concentration could be produced by a large lateral variation in electrical conductivity in *D"* locking in added flux that would otherwise diffuse through the region.

STUDIES OF LATE CENOZOIC GEOMAGNETIC FIELDS IN ICELAND

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Outcropping basement rocks in Iceland are mostly basalt lava flows of around 10 m average thickness, erupted 0 – 15 Ma ago. Following the efforts of J. Hospers and others in the 1950's, paleomagnetic sampling in the Icelandic lava pile (as described in published laboratory studies) has amounted to: 1500 flows in 1960-71, mostly in Eastern Iceland; 3000 flows in 1972-79, largely in K-Ar dated composite sections in various parts of Iceland; 1700 flows in 1980-95, also mostly in composite sections. In these three periods the most common number of oriented samples/flow was 2, 3 and 4 respectively. Results from several sample collections remain to be published. Sampling has emphasised well-exposed lava profiles with minimal disturbance from tectonics and hydrothermal alteration. Little has been collected yet from intrusives, interbasaltic sediment beds, Holocene volcanics, or wet sediments. Icelandic lavas are characterized by the simplicity of measurement of primary remanence direction, stability, and consistency of directional results. Individual flow-mean directions are very reproducible between sampling sites and/or different investigators, and the angular distribution of these is also similar between data sets of 300 flows or more. Main uses so far include: local stratigraphic correlation by using reversals (and occasionally excursions) - studies of the overall secular variation (which is greater than predicted by some models) - studies of transitions/excursions (rarely recorded in any detail) - radiometric dating of polarity boundaries - anomaly interpretation. A few paleointensity studies have been made, not always with satisfactory results.

SECULAR VARIATION AS RECORDED IN PERMIAN REDBEDS FROM DOME DE BARROT, FRANCE

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The Permian redbeds of the Dôme de Barrot (Southern France) show variations in the NRM directions which resemble those of secular variation. To verify secular variation during a Superchron, a precise time control is required. The cyclic sedimentation pattern of the redbeds provides control on duration: if we assume the cyclicity to represent the precession cycle of the Earth, the sedimentation rate is approximately 12.5 cm/kyr. A preliminary study of the NRM, measured over one depositional cycle (5 cm sample spacing), reveals that inclination varied from -35 to 15 degrees and declination from 195 to 225 degrees. This suggests that during a Superchron declination and inclination swings are comparable to the present-day secular variation. Currently a high resolution study (< 1 cm sample spacing) of the NRM directions is carried out. The aim is to investigate whether the observed variations in directions represent purely geomagnetic field variations, or are affected by diagenetic processes.

COMPARATIVE ANALYSIS OF THE SPECTRA OF THE GEOMAGNETIC FIELD AND SUNSPOT NUMBERS

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A method of nonlinear spectral analysis, named by the method of the global minimum (Planet. Space Sci., 1997, 241) has been used to find the spectrum of the longest set of the geomagnetic field measurements at Hartland observatory for 1810-1995. Analysis of the calculated spectrum shows that measured geomagnetic field consists of stochastic and periodic parts. The spectrum of annual geomagnetic field has the powerest spectral peak at overlong period T=4761 yr in H which could be the 2-nd harmonics of the well-known period T~1000 yr found in paleomagnetic data. The next (in accordance to the power) period is T=334 yr derived earlier from radiocarbon data. These peaks could be connected in principal with geodynamo. Comparative detail analysis with spectrum of annual sunspot numbers for 1700-1995 calculated by us shows that significant spectral peaks of the geomagnetic spectrum are at the periods that (within error accuracy) coincide with relevant solar periods: Gleissberg's (T=86 yr), Frits's (T=55 yr), Briekner's (T=36 yr) cycles and others. These results presume that energy of the Earth's core does not depend from dynamo mode in this region of periods; preferable mode is determined by the external action (the Sun).

MORPHOLOGY OF GEOMAGNETIC FIELD CREATED BY EARTH'S INTERIOR CURRENT LOOPS

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The possible configurations of current loop systems are estimated that could model the main peculiarities of the Earth's magnetic field. These peculiarities are dipolar form, world magnetic anomalies. The current loops system parameters are estimated that must be varied to provide the observed secular variations of geomagnetic field. Field morphology is presented by magnetic lines in the near-earth and Earth's interior spaces, also by equal level lines on the globe (computer images).

NON-DYNAMO MODEL OF THE EARTH, PLANETS AND SATELLITES MAGNETIC FIELD GENERATION

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The new model of the magnetic field generation on the planets and satellites is suggested. This model is based on the "hot" Earth's hypothesis and the idea of the Hall's mechanism of the current generation and the increase of the initial magnetic field. This small initial field arises in the phase change "condensation-evaporation" on the inner core boundary through the daily rotation of the double electric layer. The change of regime "condensation" on "evaporation" leads to the polarity change of the double electric layer and the geomagnetic field polarity, that is the reversal. The existence of the inner core of satellites in the beginning of their evolution explains the magnetic field generation in their interior in the past.

GEOMAGNETIC FIELD INTENSITY AT HAWAII FOR THE LAST 400 KYRS FROM CORE HSDP (BIG ISLAND, HAWAII).

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More than 200 new paleointensity (Thellier-Thellier) results have been obtained from core HSDP, which penetrates about 1000 meters (230 flows) of the Mauna Loa and Mauna Kea volcanic series. At least 2 determinations are now available for most of the flows.
In general, we have observed a high percentage of succesful determinations, so that the HSDP record is the longest continuous volcanic record of geomagnetic field intensity yet reported. The average geomagnetic intensity over the entire time interval is close to the present field intensity at Hawaii. For the last ~40 kyrs, on the contrary, the intensity is lower than its present value in consistency with previous results from Hawaii (Mankinen and Champion, 1993a,b) and recent sedimentary records of relative paleointensity. Over the entire time interval there are pronounced intensity lows some of which appear to be correlated to geomagnetic events revealed by a directional study (Holt et al., 1996) and our own study. Due to a high extrusion rate, the record is very detailed between 200 and 400 kyrs and its general trends are similar to those observed in the relative paleointensity record from marine cores.

HIGH RESOLUTION STACK OF RELATIVE PALEOINTENSITY RECORDS FOR THE LAST 80 KYRS FROM NORTH ATLANTIC DEEP SEA CORES.

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We have obtained new relative paleointensity records from cores PS2644-5 and SU 90 -24 recovered from the southwestern Iceland Basin and the Irminger Basin, and from core MD 90-34 located in the Bermuda Rise. These new records were stacked together with previously obtained and partially published records from the Labrador Sea (core P-094) and from ODP Leg 162 (Site 983). The stack was made by finding the best agreement between the paleointensity records through selection of characteristic tie points, using the Analyserie program. The time scale of core PS 2644 was used as a reference, because this core is characterized by both high density AMS 14C dates since about 50 ka and a precise oxygen isotope stratigraphy. The differences between tie-point ages from individual paleointensity records and tie-point ages in the stack is usually a few kyr, but may locally reach 5 kyr for some cores in specific intervals where the oxygen isotope stratigraphy is ill defined. Significant differences between individual records are present in the 0-20 kyrs interval. In the 20-80 kyr interval, on the other hand, the stacked record is well defined and several small scale features may be correlated. This record documents a picture of the geomagnetic field with a pronounced low at 40 ka, related to the Laschamp event, a well marked broad maximum at about 48 ka then a progressive decrease to a marked low at 63 ka.

RELATIVE PALEOINTENSITY DETERMINATIONS FROM MARINE SEDIMENTS: AN EMPIRICAL CORRECTION FOR GRAIN SIZE VARIATIONS.

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We have attempted to correct normalized magnetization records from deep sea cores for the effect of grain size variation, in order to obtain geomagnetic paleointensity records from cores which do not entirely meet current selection criteria for paleointensity estimates.
Values of NRM/ARM ratios were obtained continuously on the entire length of the cores using the u-channel technique in connection with a small access cryogenic magnetometer. Values of the coercivity hc (which is considered as a proxy for grain size changes (Heider et al., 1987)) were obtained every 5 cm with an AGFM. A specific filtering technique reveals a linear relationship between hc and NRM/ARM, which has been used to correct the normalized magnetization record.
Application to Core SU90-08 obtained in the Ruddiman's zone in the North Atlantic,brings the normalized record very close to the SINT-200 profile. Furthermore, the correction reduces correlation with environmental parameters to an unsignificant level.

N → R POLARITY TRANSITION IN THE MATUYAMA FROM THE JORDAN RIFT, NORTHERN ISRAEL

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We report first results of our paleomagnetic studies of the upper Olduvai N → R transition from exposed lacustrine sediments of the Erk-el-Ahmar Formation in the Jordan River valley, just south of the Sea of Galilee, Israel. We sampled and measured more than a hundred specimens from a 5 m section, and the stable characteristic remanence was obtained by stepwise alternating fields demagnetization. From Magnetostratigraphy the estimated average sedimentation rate is about 0.25 mm/yr (25 cm/ka). A nearly antipodal reversal occurs in about 5 cm--on the order of 200 yrs. In the 6 ka that precede this boundary there are two zones of sub-horizontal inclinations, where the declinations are rotated counter-clockwise about 30°. The more persistent of these episodes is about 0.75 m (~3 ka) below the reversal of the directions. Outstide these zones the field has regular normal or reverse directions. We are currently assessing these sediments as candidates for relative paleointensity determinations.

DETERMINATION OF THE ANCIENT GEOMAGNETIC FIELD INTENSITY USING THE MESOCAINOZOIC PERIOD EFFUSIVE ROCKS OF ARMENIA

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Information about the H(anc) is important both for study of the Earth core evolution and development of the geomagnetic field generation theory. In the present work the results of H(anc) determination by means of mesocainozoic effusive rocks are given. The investigation was carried out according to Telye and H(e) method. With the purpose of distinguishing the samples suitable for H(anc) determination a complex of laboratory investigations was applied which included thermomagnetic analysis by means of I(st) and I(s) curves, making of I(n), I(n) curves as well as the coercive spectra by means of I(n) I(ri) and I(n). According to the laboratory investigations analysis the collection of effusive rocks was divided into 3 groups regardless of I(n) age and polarity. Ferromagnetic fraction of the first group is represented mainly by magnetite, which is the bearer of thermoresidual magnetism to the time of formation of these rocks. In the second group primary magnetite and secondary titanomagnetite are available. I(n) of these rocks is thermoresidual. In the third group the ferromagnetic fraction is represented by primary magnetite and maggemite of secondary origin. For the H(anc) determination all the samples of first and second groups were used, as well, as well as a part (with good Telye curves) of the third group. On the average the H(anc) value is near to the contemporary one, but certain increasing is observed from the Iurassic till Quaternary period.

REVIEW OF THE LASCHAMP EVENT - PALEOMAGNETIC SIGNATURE AND NEW AGE DETERMINATIONS BY AMS^{14}C

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Paleomagnetic investigations performed on volcanic rocks near a small village called Laschamp 30 years ago clearly revealed intermediate to almost reversed directions defining the Laschamp event. Although the results were subject of doubts, mainly because of inprecise age determinations, finally this geomagnetic event could be verified at different locations over the globe. Many records of the Laschamp event (and also other events) could be derived especially from marine sediments mainly from northern, but also southern, high latitudes, where always a full reversal of the local field vector could be detected. A lot of different rock magnetic investigations performed on these sediments proved that normal and reversed directions are carried by the same magnetic mineral assemblage and are not due to disturbances of the sediments.
New uncalibrated AMS^{14}C determinations yielded an age range of 31 to 34 ka. However, these ages have to be shifted backward in time by several thousands of years as especially the Laschamp event is linked to very low field intesities. This could be shown by absolute intensity determinations on volcanics as well as by relative paleointensity estimates from sediments.

MAGNETOSTRATIGRAPHY OF LONG SEDIMENT CORES FROM LAKE BAIKAL, SIBERIA, SITES BDP-93 AND BDP-96

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In 1993 two ca. 100m long sediment cores were drilled at the Buguldeika Ridge in Lake Baikal (Cores BDP-93-1 and -2). A collection of 894 samples taken from BDP-93-2 at about 8cm intervals was analyzed for high-frequency variations in magnetic susceptibility and paleo-magnetic directions and intensity. During the drilling campaign in 1996 on the Academician Ridge a 196m long core (BDP-96-1) and a 100m long core (BDP-92-2) were recovered. Samples each 20 cm from this site yielded a detailed polarity sequence that was correlated to the geomagnetic polarity time scale. In general, sedimentation rates on the Academician Ridge are lower by a factor of 6 when compared to Buguldeika Ridge.

STATISTICAL ANALYSIS AND MODELING OF VARIATIONS IN THE GEOMAGNETIC FIELD

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Power spectral analyses of the dipole moment of the earth's magnetic field inferred from ocean sediment cores and archeomagnetic data from time scales of 100 yr to 4 Myr have been carried out. The power spectrum is proportional to $1/f$ where f is the frequency. These analyses compliment previous work which has established a $1/f^2$ spectrum for variations at time scales less than 100 yr. Power spectral analyses of inclination and declination inferred from lake sediments from time scales of 10 yr to 30 kyr have also been performed. The spectra are constant above time scales of 3 kyr, proportional to $1/f^2$ from time scales of 500 yr to 3 kyr, and constant again below time scales of 500 yr. The 3 kyr time scale is associated with the decay time of the quadrupole moment. We test the hypothesis that reversals are the result of variations in dipole intensity with a $1/f$ spectrum which occasionally are large enough to cross the zero intensity value. Synthetic binormal time series with a $1/f$ power spectrum representing variations in the earth's dipole moment are constructed. Synthetic reversals from these time series exhibit statistics in good agreement with the reversal record. $1/f$ noise behavior is reproduced with a model of magnetic diffusion in the earth's core driven by dynamo action modeled as a random amplification or destruction of the local magnetic field.

PALEOMAGNETIC FIELD INTENSITY RECORDED IN LOESES OF THE UZBEKISTAN, 53-22 KA

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The time interval with two geomagnetic excursions Mono and Kargapolovo (the age of excursions are about 28 Ka and 45 Ka respectively) was taken for estimation of paleointensity near and during the excursions. These excursions have been studied in the loese section Uzbekistan, which was made in bored well. The estimation of relative paleointensity (F) was accomplished using the measurements of Rnst= Int/Irst after the samples heating with 350 C. The thickness scale data were converted to the time scale and correspond to the age 53 - 22 Ka. Rns curve was compared with the other paleointensity records from 60 Ka to the present time. This allowed to compare F with the value of modern dipole moment field (Fp). The global maximum of F, exceeded Fp in 1.3 times, corresponds to the age 51 Ka. The average reduction of F up to 0.4 Fp have been registered from 50 - 35 Ka. The second maximum with the amplitude less than Fp was registered for 35 - 24 Ka. It is devided by the short-time minimum, corresponded to the age 29-27 Ka. The excursion Kargapolovo occured during the first minimum, the excursion Mono occured during the second one. The low mean values of F have been obtained not only during geomagnetic excursions, but also before the beginning of excursions and after the termination of its. The geomagnetic periods of secular variations of F are close to the periods of angles variations (declination and inclination) and the periods of variations of scalar magnetic parameters.

The Earth obliquity oscillations, probable cause of the magnetic polarity reverses.

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The palynology of the Cretaceous/Tertiary and the Plio/Peistocene transitions shows the "tropical" floras proceeded up the paleolatitudes during the normal polarity chrons while the "boreal" floras proceeded down them during the reversed polarity chrons.
Eco-climatologically these migrations give place to an alone explanation: the Earth obliquity oscillations.
Then it is suggested that these obliquity oscillations have also governed the geomagnetic polarity, that by the way of the Earth precession alternatings: reversed polarities during the positve precession times and normal during the retrograde ones, like to day.
The prime cause of the whole process could be the slow movements of materials inside the mantle (rotational wants of balance / gravital requilibrations)

PALEOMAGNETISM AND PALEOINTENSITY RESULTS OF LATE CRETACEOUS BASALT FROM MADAGASCAR

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145 cores (15 sites) were drilled in the late Cretaceous flood basalt (~88 Ma) located in the northwestern part of Madagascar. Samples were studied by conventional thermal and alternating field (AF) demagnetization. Most of the samples were affected by lightning, inducing an IRM. In many cases the remagnetization was only partial and could be removed by AF. Nine sites out of 15 yielded a reliable site-mean direction and a paleomagnetic pole of l=75.4 N, f=228.9 E, A95 = 4.8 , k = 116.8, N = 9 was obtained. This pole is statistically identical to the late Cretaceous paleomagnetic pole obtained for Africa, and hence, indicates that drift of Madagascar away from Africa had ceased prior to the volcanism (~88 Ma) as also supported by the magnetic lineations of the western Somali Basin. Only one site seemed completely unaffected by lightning, and a paleointensity of 61.5 ± 5.5 mT (VDM = 10.7 ± 0.9 Â 1022 Am2) was obtained using the Thellier paleointensity technique. This intensity is somewhat higher than previously published results from the Cretaceous Normal Superchron.

LONG TERM VARIATIONS OF THE MAIN GEOMAGNETIC FIELD FEATURES : GLOBAL VERSUS REGIONAL ANGULAR SCATTER

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Long term features of the MGF, angular standard deviation (ASD) of VGP, as well as dipole moment and reversal rate, seem to covariate during Phanerozoic : high reversal rates and ASDs are observed during paleointensity lows in Tertiary and Jurassic periods. We will concentrate on ASD variation versus time, checking how robust is the global average model with respect to the problem of a priori or recursively adjusted cutoff angle and compared to regional studies. Examples from Galapagos hot spot (0-2 Ma), Ethiopian (30 Ma) and Deccan (65 Ma) traps, together with the Esterel volcanics (270 Ma) will be detailed. For the Tertiary the case for low dipole and relatively strong non dipole field will be discussed.

SOME ASPECTS OF PLIO-QUATERNARY GEOMAGNETIC FIELD IN GEORGIA (CAUCASUS)

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Since L. Vekoua's 1961 pioneering study, several paleomagnetic works were devoted to the Georgian Plio-Quaternary volcanics (Sologachvili, 1986 ; Camps et al., 1996 ; Goguitchaichvili et al., 1997). In total more than 400 lava flows coming from 47 sites were studied. In most cases a single magnetization component was detected, generally carried by a Ti-poor titanomagnetite. In general the the magnetozones correlate reasonably well from site to site. Combined paleomagnetic and geocronological data suggest that almost all geomagnetic polarity chrons are recorded in these rocks since 4 M.a. Paleointensity studies using mainly the Thellier method provide evidence for a relatively low field during reversals in comparison to both the post or pretransitional geomagnetic fields. A field reduction seems to occur sometime just before reversal.

300 KYRS OF GEOMAGNETIC PALEOSECULAR VARIATION DURING THE BRUNHES PERIOD FROM A VOLCANIC SECTION AT EL HIERRO (CANARY ISLANDS).

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A sequence of 69 flows was sampled in the El Golfo formation at El Hierro (Canary Islands). Radiometric datings at 8 regularly spaced stratigraphic horizons bracket this section between 442 ka and 133 ka. Thermomagnetic analysis indicate that the magnetic carriers are magnetites or titanomagnetites with variable Ti-content. AF and thermal stepwise demagnetization isolate the same single stable normal polarity component. The mean inclination is shallower than expected from the axial dipole field resulting into VGPs laying beyond the geographic pole. The VGP scatter is consistent with McFadden's data base and model G. However, in the lower part of the section declinations appear to be deviated eastward by some 15°, suggesting that this part may have undergone a clockwise rotation. This hypothesis is not inconsistent with the known structural pattern of El Hierro. The scatter of the VGP with respect to the mean pole appears to be significantly smaller in the lower part of the section than in the upper part. As there is no evidence for high variation of the extrusion rate, this may indicate that the amplitude of the paleosecular variation was slightly reduced in the Canary Islands in this period.

SEDIMENTARY RECORDS OF GEOMAGNETIC PALEOINTENSITY: WHAT CAN WE BELIEVE IN

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Sedimentary records of relative paleointensity have come a long way towards achieving credibility in the main stream of paleomagnetism. We have known for decades that sediments acquire a remanent magnetization whose intensity is a function of the ambient magnetic field. We also have known that the relationship between the applied field and the remanence is complicated by mineralogy, depositional environment, post-depositional processes, and so on. Accounting for the latter to extract the former is the entire art of producing relative paleointensity records. I will discuss methods of normalization and methods of verification of relative paleointensity records in sediments.

AN ULTRAHIGH RESOLUTION RECORD OF HOLOCENE PALEOSECULAR VARIATION FROM SAANICH INLET, VANCOUVER ISLAND, BRITISH COLUMBIA: INITIAL RESULTS

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Saanich Inlet, a fjord on Vancouver Island, British Columbia, has a Holocene rate of sedimentation on the order of several millimeters per year. Moreover, the sediment at the site is varved so that Saanich Inlet has the potential of providing an ultrahigh resolution record of Holocene paleosecular variation. In 1996, two sites in the inlet were cored during ODP Leg 169S. A complete suite of U-channel samples was collected from two overlapped holes at each site. High-resolution correlation between each pair of holes was achieved by x-radiography of the varves in the U-channels. After removal of a very soft drilling overprint, the sediment of Saanich Inlet appears to provide an excellent record of Holocene geomagnetic field behavior. Initial indications are that this record contains the same features as the record of Holocene paleosecular variation from Fish Lake, Oregon.

PROBLEM OF ELIMINATION OF DIRECTIONNAL DATA CLUSTERS IN PSV STUDIES

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The paleosecular variation (PSV) of the geomagnetic field is often described by angular standard deviation of paleomagnetic directions obtained on volcanic rocks. The main part of PSV data comes from volcanic sequences which present the advantage to show chronological successions and consequently to highlight the possible data clusters associated to rapid lava extrusion. The definition of these clusters is often subjective but McFadden et al. (1996) proposed a relatively objective statistical method to rationalise the flows that have repeatedly sampled the same geomagnetic field vector. We highlight different problems relative to application of this kind of method and we propose here another approach considering the location of studied directions in the distribution.

CHAOS IN GEOMAGNETIC REVERSAL RECORDS: COMPARISON OF REAL AND MODEL DATA

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The time series of geomagnetic field reversals (GFR) is very irregular, number of well dated reversals in the Earth's history being not more than 300. This is too little for correct determination of statistical properties of a reversal process, and is only enough for determination of variation intervals for these parameters. Time series generated by Rikitake disk dynamo model has been calculated for the comparison with the real GFR time series. Some remarkable differences between real and model data have been revealed, such as time scale error of the real data. This problem has been taken into account for the construction of the model time series. Variation limits of statistical properties of the model data (types and parameters of distribution, correlation dimension) have been revealed. Statistical properties of distribution of reversal moments as well as the correlation dimension have been found to strongly depend on determination precision of reversal moments in time series generated by the dynamo model.

Real and model data have displayed good correlation, i.e.: behavior of the geomagnetic field can be described using the system with low correlation dimension similar to the two-disk dynamo model.

SE34 Rockmagnetism, palaeomagnetism and environmental magnetism

Convener: Hoffmann, V.

03 Effect of chemical alteration on magnetization

Convener: Özdemir, Ö.
Co-Convener: Roberts, A.P.

TSC TECHNIQUE APPLIED TO THE CHARACTERIZATION OF SEDIMENTARY LITHOLOGIES AT THE PERTIGALETE SEQUENCE (NORTHEASTERN VENEZUELA)

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Thermally Stimulated Current (TSC) Technique is used here to characterize a lithological contact at the Pertigalete sedimentary sequence (Cretaceous northeastern Venezuela). TSC technique studies the dielectric relaxations of a material that contains polarizable entities. Six samples, collected near a contact identified in the field as that between Chimana (CH) and Querecual (QC) formations, were studied. The complex spectra obtained in the temperature range from 77 to 320 K, indicate a straight difference between the CH and QC samples. The broad spectra, separated by using Direct Signal Analysis, show the presence of three overlapping peaks for the CH samples and four for QC. As we approach to the contact, the mean energy value for each separated process indicates the existence of a transitional change of lithologies. Comparison with IRM and Lowrie experiments, performed here in order to magnetically characterize lithologies and discontinuities in the sedimentary sequence, corroborates TSC results and indicates the potential of this technique as an alternative tool in stratigraphy.

ST34

LOWRIE IRM EXPERIMENTS IN SAMPLES OF THREE OIL WELLS AT LA VICTORIA FIELD (SOUTHWESTERN VENEZUELA)

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In previous rock magnetic studies of wells LVT-1X, 4X (producers) and 2X (non producer) located at La Victoria oil field (southwestern Venezuela), we demonstrated a causal link between anomalies of NRMs and bulk magnetic susceptibility values, at near surface levels, and the presence of secondary magnetic minerals such as spherical aggregates of authigenic magnetite crystals and iron sulfides. In order to better identify these secondary magnetic phases we have conducted now stepwise thermal demagnetization of composite IRMs (Lowrie IRM experiments) in whole rock samples of drilling fines. These results are complemented by X-ray diffraction analyses, IRM acquisition and thermoremanence curves, and transmission (TEM) and scanning (SEM) electronic microscopy. At the anomalous NRM and susceptibility levels (ca. 600 m) we have identified: authigenic magnetite (spherical aggregates), goethite and greigite for LVT-1X and 4X, and pyrrhotite, goethite, hematite and autigenic magnetite (spherical aggregates) for LVT-2X. The stability and coexistence of these magnetic minerals can be used as a diagnostic test of the oil quality and the themochemical conditions that prevail in the reservoir suggesting, for La Victoria field, temperatures of ca. 100°C, pressures of ca. 300 bar, Ph>7.5, Eh low to medium, an anaerobic environment and a high content of sulfur in the oil.

PRELIMINARY RESULTS OF CHEMICAL REMAGNETIZATION UNDER UNIAXIAL COMPRESSION

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The studies of an influence of stresses on a direction of remanent magnetization acquired during chemical changes are very important for paleomagnetism of deformed regions. For this purpose preliminary experiments were carried out in the Rock Magnetic Laboratory of the Geophysical Institute in Prague, Czech Republic. Non magnetic press was used for uniaxial compression. Sister samples were cut from sedimentary rocks containing sulphides. Samples have initial remanent magnetization aproximately in vertical direction opposite to ambient field in the laboratory. One sample from a pair was heated to 350 or 400° C. Second sample was heated to the same temperature and compressed during heating and cooling in the Z direction of sample coordinate system. Remanent magnetization acquired during experiment were found by subtracting initial remanence from final one. We found that in the conditions of our experiment remanence acquired during compression differ in declination about 90° from the remanence acquired without compression. On the other hand compression did not influence directions of anisotropy axes but changed the shape of anisotropy ellipsoid into triaxial one.

ROCK MAGNETIC CHARACTERIZATION OF A FORMATIONAL CONTACT IN CRETACEOUS STRATA (EASTERN VENEZUELA)

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Magnetostratigraphic studies at the Albian-Cenomanian time boundary in the Querecual/Chimana formational contact (northeastern Venezuela) indicate reversed secondary NRM's. By integrating manifold rock magnetic evidence we argue that this contact has acted as a major focus of hydrothermal alteration and consequent remagnetizations in the adjacent strata. Anomalies of susceptibility and total NRM values, at the surroundings of the unconformity, reveal the dominant presence of secondary magnetic minerals (i.e. magnetite and pyrrhotite), the likely products of anoxic conditions that prevailed during times when the basin reached its maximum temperatures and oil was generated (Lower Miocene). However, most stable remanences reside in the highest T_B's and H_C's magnetic minerals (i.e. hematite). Although from the NRM stratigraphic profile hematite does not seem to be conditioned by the contact itself, Lowrie IRM experiments clearly demonstrate that this mineral is also a by-product of alteration dating from times when oxidizing conditions dominated the basin, probably long before the oil window was attained. Rock magnetic properties have proved here as an effective tool for characterizing discontinuities in the sedimentary sequence which otherwise could pass barely detected by conventional biostratigraphic and lithostratigraphic studies.

CRM EXPERIMENTS AND PSEUDO-PALEOINTENSITY MEASUREMENTS ON BASALTIC ROCKS WITH INITIALLY LOW CURIE TEMPERATURES

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We report about different long time experiments at high temperatures for producing an artificial CRM or a mixture of CRM and TRM, results of paleointensity experiments on those oxidized samples and rockmagnetic investigations before and after oxidation.

Paleointensity experiments yield different values for the intensity of the "paleofield" (here: field which was applied during acquisition of CRM), depending on the previous CRM experiment: samples in which the CRM was produced during long heating at a constant temperature in an applied field show a resulting paleointensity of about half of the value of the applied field during CRM acquisition. Samples which acquired a CRM and TRM during slow cooling show resulting paleointensities slightly higher than the intensity of the applied field during CRM and TRM acquisition. Results will be discussed on natural basalts from southern France.

INFLUENCE OF HEAVY METAL CATIONS ON THE HYSTERESIS PROPERTIES OF IRON-OXYHYDROXIDES

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Iron-oxyhydroxides formed in aqueous environments have high specific surface area and a relatively open structure, which facilitates the adsorption of heavy metal cations, such as zinc, lead and mercury. Preliminary results indicate that in natural environments, the adsorption of these heavy metal cations can produce measurable changes in the coercivity of the iron-oxyhydroxides. In particular, sampling of iron-oxyhydroxides downstream from abandoned mine sites shows a trend toward decreasing coercivity with increasing heavy metal absorption. This relationship is being tested by comparing changes in the coercivity of iron-oxyhydroxides produced under controlled conditions in the laboratory and subsequently exposed to solutions with known concentrations of dissolved heavy metal cations. These results imply that the attentuation of heavy metals in the natural environment is influenced by geochemical changes in the iron-oxyhydroxides during the precipitation cycle, and that the magnetic properties of iron-oxyhydroxides are sensitive to the presence of heavy metal cations.

THE CAUSE FOR SECONDARY CHEMICAL MAGNETIZATION OF PARTICOLOURED ROCKS OF THE TATARIAN STAGE

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A number of reference sections of the Tatarian Stage of Russian Plate contains unstable palaeomagnetic areas. This phenomenon relates to both ancient and modern metachronic magnetization.

To study the nature of secondary magnetization, continuous sampling was carried out which covered 30 m-thick section with sampling density of 15 to 17 samples per 1 m.

Results of the field and lab studies indicate that areas of secondary chemical magnetization occur at the boundaries between different facies, and that this magnetization is caused by migration of ferrous oxide from the reduction environment into oxidized rocks.

EFFECT OF CHEMICAL CHANGES ON MAGNETIZATION

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Chemical alteration of magnetic minerals in rocks and sediments produces chemical remanent magnetization (CRM), which partially or totally replaces their original remanent magnetization. In the single-phase oxidation of titanomagnetite to titanomaghemite or of magnetite to maghemite, there is a chemical change without any major change in the spinel crystal lattice. Experiments show that CRM in fine-grained titanomagnetite inherits the original remanence direction. Magnetic coupling between the two phases remains intact throughout. However, many naturally occurring oxidation (magnetite → hematite), reduction (hematite → magnetite), and inversion/dehydration (maghemite → hematite, goethite → hematite, lepidocrocite → maghemite → hematite) processes transform the crystal structure of the magnetic phases. Magnetostatic or exchange coupling may nevertheless deflect the daughter- phase CRM from the direction of the external magnetic field. The resulting intermediate-angle CRM's record neither the direction of the parent remanence nor the field direction. It is vital to recognize and erase phase-coupled CRM's of this type, which generate spurious paleomagnetic directions.

ALTERATION OF MAGNETIC SIGNALS IN EASTERN MEDITERRANEAN SEDIMENTS

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Core KC19C (19.6 m long) was recovered in the abyssal plain between Crete and Cyprus (water depth 2750 m). It contains a large number of organic-rich layers (sapropels), which correlate to maxima in the insolation curve. Porewaters contain sulphide down from a few meters below seafloor (mbsf), which is anomalous in the eastern Mediterranean. We have studied the geochemical characteristics of these porewaters and sediments, as well as a series of magnetic parameters and ratios. Downcore, the following observations are made: Fe and Mn (hydr)oxides occur in the top, at the oxic-suboxic transition just above the youngest sapropel Si2 at 0.4 mbsf. These (hydr)oxides can be more easily demagnetized by alternating fields than (hydr)oxides further down. The transition from suboxic to anoxic sediments is located at about 2 mbsf. Sulphide is envisaged to be formed at ~17.5 mbsf, probably during sulphate reduction by methane oxidation. From 17.5 mbsf sulphide has migrated upward, titrating reactive Fe, resulting in pyrite formation in the entire sediment column up to 2 mbsf. Therefore, magnetic intensities are significantly reduced down from about 2 mbsf, and no reliable NRM data can be obtained in the lower half of the core. (Sponsored by EU programs MAST-2 (CT93-0051) and MAST-3 (CT97-1122), and MJD by KNAW.)

CHEMICAL ALTERATION OF MAGNETIC MINERALS IN NATURE AND PALEOINTENSITY EXPERIMENTS ON VOLCANIC ROCKS

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Titanomagnetite in volcanic rocks is commonly transformed by weathering, hydrothermalism or exsolution-oxidation. Low temperature oxidation (maghemitization) is generally considered as a typical effect of weathering, although this transformation probably starts during the initial flow cooling (Prévot et al., 1981; Kent and Gee, 1996). Maghemitization modifies all magnetic properties, and the natural remanence is no longer a TRM. Surprisingly however, Thellier paleointensity experiments on young pillow-basalts can provide splendid Arai diagrams (Prévot et al., 1983) and correct paleostrength (Kent and Gee, 1996). Hydrothermalism induces profound changes in magnetic mineralogy and results in CRM acquisition. Laboratory experiments on basaltic rocks containing high-titanium titanomagnetite oxidized in air at moderate temperature (400°C) for several days show that the CRM so produced provides a nice Arai diagram but a much too low paleostrength. The remanence of most volcanic rocks used for paleointensity experiments is carried by very fine exsolutions of near-magnetite resulting from a 'high temperature' exsolution-oxidation supposed to occur above 600°C. In fact, this transformation can continue to much lower temperatures in nature (Grommé et al., 1969). It is encouraging that preliminary experiments show that the CRM-TRM produced by laboratory oxydation of titanomagnetite during slow cooling in air from 500°C provides reasonably correct paleostrength.

SEDIMENTARY GREIGITE (Fe_3S_4): OCCURRENCES, FORMATION AND MAGNETIC PROPERTIES

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Greigite is widely considered to be a minor magnetic mineral, but its presence is being increasingly reported in a variety of environments, including anoxic lake and marine sediments, marshes/estuaries, coal beds, magnetotactic bacteria, gas hydrate deposits, and low-temperature hydrothermal ore deposits. If greigite is present in a sedimentary sequence, it will have important implications for environmental magnetic studies because in situ formation of diagenetic phases invalidates studies that rely solely on a detrital remanent signal (e.g., relative paleointensity and catchment studies). Also, time lags between lock-in of detrital and diagenetic remanences will complicate studies of geomagnetic field behavior, particularly high-frequency variations. The reported worldwide occurrences of greigite, mechanisms of greigite formation, an overview of known magnetic properties of greigite, with criteria for "fingerprinting" greigite-bearing sediments, and speculations on possible environmental implications of identification of sedimentary greigite will be discussed in this presentation.

ROCK MAGNETISM AND PALAEOMAGNETISM OF GREIGITE-BEARING MUDSTONES IN THE ITALIAN PENINSULA

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Ferrimagnetic iron sulphide minerals are widespread in the Italian Neogene and Quaternary fine-grained sediments. We carried out a variety of rock magnetic measurements on a collection of samples, in which greigite (Fe_3S_4) was supposed to be the main magnetic carrier. We show that although positive identification of greigite by magnetic methods can be reached solely by combining a variety of magnetic properties, a first indication of its occurrence in a sediment is the presence of properties typical of an assemblage of single-domain grains. Paired samples were also investigated to make a detailed comparison of the palaeomagnetic behaviour with respect to different laboratory demagnetization treatments (thermal, static and tumbling alternating field demagnetization). The results clearly pointed out that thermal demagnetization is the most effective treatment for the isolation of the characteristic remanence magnetization carried by greigite, whereas AF demagnetization produces spurious magnetic remanences (gyroremanence and rotational remanence) at fields larger than 40 mT.

EFFECT OF DOLOMITIZATION ON MAGNETIZATION OF ESTONIAN CARBONATES

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Magnetic susceptibility and chemical composition of Ordovician and Silurian secondary dolomites of five various origin were studied and compared with surrounding them limestones. During different genesis dolomitization chemical composition of rocks was changed variously. The magnetic susceptibility of Estonian limestones was determined in the range of $(-1-5)*10^{-5}$ SI which is caused by 0.4-0.9% of Fe_2O_{3total} content. The most remarkable process in Estonian carbonates is increase in total iron content during dolomitization. Increase of Fe_2O_{3total} up to 2.83% were determined in the Lower and Middle Ordovician widespread dolomite layers. This caused the increase in magnetic susceptibility of rocks up to $22*10^{-5}$ SI. The less but still significant increase in Fe_2O_{3total} (up to 2.5%) and in magnetic susceptibility up to $13.8*10^{-5}$ SI were measured in the Middle Ordovician dolomites associated with fracture zone. The increase of total iron content in Silurian and Upper Ordovician dolomites is less (up to 1.7%). Secondary magnetization in the fracture zone and widespread dolomite layer of Väo formation was caused by substituting of Mg^{2+} by Fe^{2+} together with Mn^{2+} in the crystalline lattice of dolomites. In the Lower Ordovician dolomite layer it was caused by increase of Fe_2O_3 occurring in the form of the hematite in the carbonate matrix.

HERCYNIAN NEOMORPHISM AND GENESIS OF THE NAVAN Pb-Zn DEPOSIT, IRELAND, FROM PALEOMAGNETISM

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The Outokumpu Zinc - Tara Mines Pb-Zn deposit at Navan near Dublin, Ireland, is Europe's largest zinc mine. It is hosted in Courceyan (~356 Ma) platform carbonates with basal red beds of the Navan Group that rest on Ordovician basement. Mined sphalerite-galena mineralization and reserves exceed 79 Mt. of ~8.3% Zn and 2.6% Pb. The group is unconformably overlain by an Arundian (~345 Ma) boulder conglomerate. It was later folded and faulted during the Paleozoic Hercynian orogeny, and cut by Tertiary diabase dikes. This study provides the first direct date for mineralization of much-debated genesis. From a start of 489 specimens, 282 (108 block samples, 26 sites) were subjected to detailed AF and thermal step demagnetization and 15 to saturation isothermal remanence analysis. A Tertiary dike gives a positive paleomagnetic contact test with disseminated ore. The Arundian clasts and Hercynian folds give negative conglomerate and fold tests, respectively. Massive and disseminated ore, barren dolostones and limestones, red beds and clasts all retain the same characteristic remanent magnetization (ChRM) direction, giving a pole at 27.8°W, 30.9°S (dp = 1.3°, dm = 2.7°) that indicates an age of ~330 ± 7 Ma. These results indicate that the Hercynian orogeny was waning in the area by this time, that neomorphism had reset the ChRM in the carbonate host rocks, that chemical remagnetization had occurred in the red beds, and that the mineralization was emplaced by fluid flow at this time.

MAGNETIC PROPERTIES OF A HOLOCENE LAVA FLOW IN CENTRAL MEXICO

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Previous paleomagnetic measurements on the 8000-years-old Tres Cruces lava flow (Central Mexico) showed that 'paleointensities' determined with help of the Shaw method range from 26.02 ± 1.67 up to 62.01 ± 1.67 μT (Gonzalez et al., 1997)

Aim of our research was to study the origin of these large 'paleointensity' variations. For this purpose, 'paleointensities' were also determined with the Thellier-Thellier method and thermal alterations were detected by measuring ARM, IRM and hysteresis loops after each heating step. These results were validated by high- and low temperature measurements before and after heating.

Our results indicate that the remanence is carried by: (1) A titanomagnetite with an unblocking temperature of ca. 350 C and (2) a (titano)magnetite having an unblocking temperature close to 580 C. Formation of hematite during heating seems limited, possibly related to the large grain size. However, above 500 C the Ti-rich titanomagnetite is replaced by magnetite-ilmenite intergrowths. Implications of this finding for paleointensity studies will be discussed.

SE34 Rockmagnetism, palaeomagnetism and environmental magnetism

Convener: Hoffmann, V.

04 Sediment magnetic records of climatic cycles and events

Convener: Williamson, D.
Co-Convener: Geiss, C.

REMAGNETISATION OF DEVONIAN LIMESTONES IN THE ARDENNES IN CONNECTION WITH FLUID FLOW AND DEFORMATION

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Deformation in the Ardennes is mostly localised in north directed thrust shear zones associated with E-W trending folds (Late Carboniferous). Orogenic fluids are likely to have used the shear zones as channels for fluid flow. At a later stage, between the Permian and Jurassic, Mississippi Valley Type (MVT) Pb-Zn and barite deposits were formed, associated with extensional structures.
Two ancient NRM-components have been found in the Devonian to Carboniferous limestones of the Variscan Belt of the Ardennes. The first HT-component (>400°C) pre-dates the folding event, but is secondary. The second LT-component (400>T>580°C) post-dates folding.
We will present results of a study linking the occurrence of the two NRM components with deformation and associated fluid flow. This is done by an analysis of thermal demagnetisation diagrams of Givetien limestones from a large number of sites and rock magnetic studies to constrain which minerals can be carriers to the two NRM components. The rock magnetic properties will be related to the development of the microtextures by microstructural and microchemical analysis.
The preliminary evidence indicates that the HT-component is associated with the late Carboniferous deformation and orogenic fluids, whereas the second LT-component is associated with fluids associated with the MVT-deposits.

HIGH RESOLUTION MAGNETIC AND MINERALOGICAL RECORD OF PALEOENVIRONMENTAL CHANGES WITHIN THE KIMMERIDGIAN-TITHONIAN FORMATIONS OF THE BOULONNAIS REGION (NORTHERN FRANCE)

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This study presents a high resolution investigation of the depositional environments of some Kimmeridgian-Tithonian sedimentary rocks of the Boulonnais (N margin of the Paris basin). This silicoclastic and carbonate sequence is, as its English equivalent, of a peculiar interest regarding to its high organic matter content and its tectonic context within the incipient N-Atlantic system. A pluridisciplinary study performed during the last few years has allowed to propose a new biostratigraphic zonation within a sequence stratigraphic framework. These first results have been used as the basis for a high resolution analysis of the magnetic and mineralogical properties of the well developed clayey intervals of the Boulonnais series. This study integrates over a 110 m thick sequence measurements of the magnetic susceptibility, of the isothermal remanent magnetization (IRM) and of a remanent coercivity ratio (S ratio). They were combined on the same samples to some grain-size and X-ray diffractometry mineralogical analyses (clays and bulk rock). The results evidence some long term and short term variations of the magnetic parameters that can be correlated to the relative sea level fluctuations deduced from the previous sedimentological studies. The origin of these cyclic variations are discussed in terms of tectonic/eustatic induced environmental changes.

HIGH-RESOLUTION RECORD OF MAGNETIC SUSCEPTIBILITY OBTAINED BY LOGGING AND TUNED BY ORBITAL FREQUENCIES

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High-resolution magnetic records have been obtained from magnetic logging of remanence and susceptibility with the Geological High Resolution Magnetic logging Tool (GHMT). In a well drilled in the North Sea for oil exploration, this tool enables a continuous measurement of the polarity of the remanence and a continuous record of the susceptibility throughout the drilled formations. A high resolution magnetic chronostratigraphy between 2.6 and 1.6 Ma is deduced from the downhole magnetostratigraphy and from a detailed spectral analysis of climatically influenced variations of susceptibility. The orbital frequencies identified on the susceptibility depth series allow a refined estimation of the sedimentation rate. Characteristic features of the onset of Northern Hemisphere glaciation and its fluctuations during the late Pliocene are identified through this analysis of the susceptibility record. As a second example, in ODP well 984 B drilled near Island (leg 162), a datation has been obtained by orbital tuning of susceptibility record using only two points dated by biostratigraphy in the depth series.

SOME PROBLEMS OF MAGNETIC RECORD OF PALAEOCLIMATE

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Numerous studies of continental sediments show the influence of climate changes on the magnetic susceptibility (K). K depends upon not only climatic, but different geological, local geochemical and other factors. Hence the discovery of real causes of K changing in different age strata demands thorough substantiation. Such investigations should be carried out with using of common methodological base. Particular attention should be paid to 1) substantiation of physical mechanism of K changing; 2) consideration of not only temporal but spatial alteration of K; 3) complex study of deposits including not only magnetic parameters of rocks but also palynological, lithologic and other data. Otherwise incorrect conclusions may be received as in the case with the studies of Alaskan and Chinese Pleistocene loess-soil sequences where climatic periodicities coordinating with astronomical theory have been calculated. Astronomical theory of paleoclimate is dominant now when global change of Pliocene-Pleistocene is concerned. But Milankovitch's theory has several discrepancies, such as a) supposition that the solar radiation is constant; b) correlation of different orbital parameters contribution to insolation, etc. It should be remembered during investigation of climate cycles and their coordinating with astronomical theory.

DETAILED STUDY OF THE MAGNETIC PROPERTIES RELATED TO CLIMATE VARIATIONS OF CORE MD95-2034

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A high resolution mineral magnetic study has been conducted on core MD95-2034 (Bermuda Rise) which covers the climat stages 6 to 2. The dominant magnetic mineral is magnetite except in two intervals. Between 15 and 18 m, high IRM peaks are correlated to black layers. Hysteresis parameters reveal the presence of greigite (Fe_3S_4) which is one of the components involved in the dissolution of iron oxides during early diagenesis. Between 40 and 45 m, low Sratio and high IRM values are observed from red sediment. They seem to correspond to hématite originating from Maritime Provinces of Canada. Variations in magnetite grain sizes and concentrations are related to source and transport changes during the 6, 5 and 4 glacial-interglacial cycles. Large grain sizes during cold stages reveal the continental erosion by ice rafting and the continual availability of the currents to advect the detrital material on the Bermuda Rise. The transition 6/5 is marked by a lack of ferromagnetic mineral which could result from a cessation of the NADW (Adkins et al., Nature 390, 1997). This interval is followed by strong and narrow peaks both in the ARM and SIRM signals, revealing an abrupt increase in the content of very fine ferromagnetic minerals. This increase is coeval with the substage 5e and corresponds to the resumption of NADW.

MAGNETIC BASED SEDIMENT-SOURCE LINKAGES IN THE PETIT LAC D'ANNECY CATCHMENT, HAUTE SAVOIE, FRANCE, DURING THE PAST 5000 YEARS

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Lac d'Annecy (460 m OD) lies in a a sub-alpine limestone catchment where land use includes intensive agriculture, deciduous forest and marginal pastoral grazing to altitudes above 1500 m. Previous studies and a more detailed recent examination of a calcareous 8 m core from the Petit Lac show mineral magnetic records of predominantly detrital inputs since c. 5000 BP with a major shift in magnetic properties at c. 1000 BP towards increased influx of topsoil probably associated with monastic deforestation and exploitation of the higher valleys. Magnetic maps of the soils in the Petit Lac catchment (c. 120 km^2), based on grid sampling at 1 km, and magnetic measurements of floodplain cores, show a wide range of magnetic mineral assemblages and concentrations that can be partly interpreted in terms of land use, drainage and surficial geology. Strong linkages between the lake and floodplain sediments and soils are established through a range of low, room and high temperature measurements of magnetisation and remanence, and are supported by evidence from pollen and organic analyses. The presentation summarises the major results, examines how the data aid an understanding of the causes and effects of climate and human impact on erosion and flooding, and makes some suggestions for optimising sediment-source linkages in other lake-catchments.

TIME EVOLUTION OF ROCK MAGNETIC PROPERTIES FROM PLIO-PLEISTOCENE TO HOLOCENE SOILS IN THE CENTER OF THE IBERIAN PLATE

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Soils from river terraces in the center of the Iberian plate (Tajo, Jarama and Arlanzón) have been well preserved since the Plio-Pleistocene. The magnetic properties of some soil profiles have been investigated with respect to the depth of each profile and in relation to the age of the terraces: low frequency susceptibility (χ_{lf}) and isothermal remanent magnetization (J_{rs}) at low and room temperature (77 K and 293 K, repectively), frequency dependent susceptibility (χ_{fd}), susceptibility of anhysteretic remanent magnetization (χ_{ARM}), hysteresis parameters (H_c, H_{cr}, J_s, J_{rs}), Curie curves and natural remanent magnetization (NRM). The contribution of superparamagnetic low and high coercivity minerals is qualitatively approved. That contribution is different in several soil horizons (enhanced surface horizon, stable B and C horizon) of each profile and their pattern of variation with age has been established. The age behaviour of most magnetic soil parameters suggests a reduced activity of the pedogenic processes in the center of the Iberian Peninsula during the Early to Middle Pleistocene.

PALAEORAINFALL ESTIMATION FOR THE LAST TWO GLACIAL CYCLES FROM THE CHINESE LOESS PLATEAU: NEW DATA

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Recently, new mineral magnetic results were obtained from the Duanjiapo site (34.2°N, 109.2°E), at the southern edge of the Chinese Loess Plateau, in a region characterized by warm and humid climatic conditions. Low-field magnetic susceptibility data alone were used for estimating palaeorainfall. The estimated differences in palaeorainfall between glacial and interglacial periods, when compared with previous studies from the Chinese Loess Plateau, are smaller, probably because of the generally greater palaeorainfall. This fact, point out the relatively humid character of this region for at least, the last ~130 kyr. These results are now compared with new data from sections along a north-south transect of the Chinese Loess Plateau, to the east of the Liupan Mountains.

CLIMATE VARIABILITY AS SEEN IN TWO INTERGLACIAL RECORDS FROM THE MIDWESTERN U.S.A.

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The sediment records from 2 kettle lakes were used to compare the magnetic signature of the Sangamon and Holocene interglacial. Pittsburg Basin in southern Illinois recorded Sangamonian climate variations, while sediment cores from Kirchner Marsh in Minnesota were used to study Holocene variations. Pollen studies from both sites indicate the occurrence of a dry prairie period in both interglcials. The magnetic response to these dry periods is quite different. In Kirchner Marsh the dry period is characterized by inceased input of detrital material, which leads to an increase in magnetic susceptibility and SIRM. The magnetic grainsize, as expressed in SIRM/ARM and hysteresis parameters, increases during the same period. Pittsburg Basin cores also shows an increase in magnetic material, but here the magnetic grainsize decreases during the dry period, and the samples show increased SD and SP contributions. In Kirchner Marsh the sediments deposited during the dry period are most likely redeposited lake sediments that have undergone additional alteration, while Pittsburg Basin prairie sediments seem to be dominated by pedogenic processes. The different response of the two lakes to a similar climatic signal shows the necessity of multiparameter studies that combine magnetic as well as non-magnetic techniques.

Sub-millennial scale variations in East Asian monsoon systems recorded by dust deposits from the north-western Chinese loess plateau.

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A new section from an extremely thick sediment sequence in the north-western part of the loess plateau (Caoxian village, Gansu Province) appears to provide a high resolution magnetic susceptibility record which spans the "Lateglacial" (last glacial / interglacial transition). The record shows several short period fluctuations in climate which can be correlated closely to the GISP2 proxy air temperature record. The observed intervals correspond to those more traditionally associated with north Atlantic / European records and include the Holocene amelioration, the Youngest Dryas, the Younger Dryas, the Allerød, the Older Dryas, the Bølling, and the Oldest Dryas. A palaeomagnetic directional record obtained from the Caoxian samples demonstrates the additional ability of the loess to act as a recorder of the ambient geomagnetic field. The determined secular variation supports the interpretation of the palaeoclimatic data and rock magnetic analysis suggests the formation of the 2 signals may be intrinsically linked.

Although the entire section is 2.25m thick and covers a period of only 12Ka it clearly demonstrates the potential of loess as an archive for high resolution records of local terrestrial climate.

EARLY PLEISTOCENE CLIMATIC CHANGES IN WEST TURKMENIA

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An about 100-meter thick of terrigenous rocks in West Turkmenia accumulated for about 300 ky. The lower and upper parts of the section cover the Matuyama chron and the Jaramillo subchron, respectively. The rhythms of various ranks with thickness ranging from 0.1m to several ten meters were observed. Bedding features, grain sorting and petrographic characteristics of these sediments point to their accumulation in a semi-closed lagoon in the arid climatic zone. Mesozoic and Cenozoic terrigenous rocks and carbonates in the adjacent area being the source rocks. Coarse-grained varieties at the rhythm bases were deposited during humid and warm intervals. Rock-magnetic and mineralogical studies revealed that the influx of magnetic minerals of local provenance decreased during these intervals resulting in lower susceptibility values. Variations of magnetic susceptibility with periods ranging from 0.6 ky to 40 ky are tentatively correlated with regional climatic cyclicity and agree with the known periods of climatic changes. The observed periods of susceptibility variation and geomagnetic secular variation are similar in this region. Their phases, however, are different, and these variations are most probably independent.

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RAPID CLIMATE VARIATIONS AND CALVING EVENTS DURING THE LAST GLACIAL IN THE SCOTIA SEA, ANTARCTICA

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We present high-resolution magnetic susceptibility (MS) data of sediment-cores taken in the southern Scotia Sea, Antarctica. The whole-core MS of core PS2319 correlates well with the dust record of the Vostok ice-core (East Antarctica) over nearly two glacial cycles. The main source area for the dust found in East Antarctic ice-cores is Patagonia. We assume that the variations in MS are controlled by the input of magnetite-rich dust originating from there. The MS is considered to reflect climatic conditions, such as aridity, weathering and wind strength, characteristic of South America and the South Atlantic. The good correlation of the MS signal of core PS2319-1 with the calcium record of the GRIP ice core from Greenland indicates that the climatic conditions responsible for the variations in the dust flux during the last glacial may have been similar in both hemispheres. Ice-rafted detritus data (IRD) from Scotia Sea are also presented and discussed in context with the Heinrich events in the North Atlantic.

ROCK MAGNETISM AND PALAEOENVIRONMENT OF LOESS/PALAEOSOL SEQUENCES

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Terrestrial high resolution palaeoclimate archives are preserved in the Quaternary loess sediments which cover wide continental areas especially on the northern hemisphere of the earth. Typically, pristine loess beds, which formed by dust deposition under cold-arid climate conditions, alternate with palaeosol layers, which developed during warm-humid periods. The evidence for these climate changes comes from palaeontological, mineralogical and palaeopedological studies. In peridesertic midlatitude regions, rock magnetic parameters such as low field susceptibility, saturation magnetization etc. are enhanced in palaeosols and weathered loess beds, most probably due to *in situ* formation of new very fine grained (superparamagnetic) ferrimagnetic minerals. Type and grain size distribution of these minerals and their modes of formation (organic by bacterial activity and/or inorganic by direct precipitation from mobilized iron complexes) are investigated at present by many student groups. One of the main research goal is to correlate the various loess properties quantitatively with palaeo-climatic factors such as rainfall or temperature.

INCURSION OF SEA WATER INTO GUCHENG LAKE DETECTED BY MAGNETIC, BIOLOGIC AND CHEMICAL DATA

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Lake sediments, covering an age from 15 to 6 KaBP, were sampled from the Gucheng Lake, China. A clear magnetic boundary exists at 12.03 m, above which susceptibility (k) and NRM intensities are much higher than below. Iron sulphide (probably greigite), magnetite and hematite are identified. Above the boundary, iron sulphide is a main magnetic contributor. Pollen and spore, as well as pigments verify that the climate quickly turned to warm and wet conditions since 11 KaBP (13.7 m). The TOC content also increases from that depth, and reaches its highest value at 12.5 m. Scour surface is detected at 12.3-12.2 m. The near-shore marine diatom and fresh-water diatom alternatively appear above 12.09 m, testifying the incursion of the sea water. Brackish water existed above 12.09 m, weakening at 6 m and disappearing at 4 m. Stronger reduction environment after sea water incursion probably favoured the formation of iron sulphide, which may lead to an increase of magnetic intensity. However, the magnetic boundary at the depth of 12.03 m lags behind other ones, which may be caused by the migration of magnetic minerals within the redox transition zone.

A MAGNETIC STUDY ON LAKE SEDIMENTS FROM ZOIGÊ BASIN, EASTERN TIBETAN PLATEAU, CHINA

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Totally 3760 magnetic samples were acquired from Core RM (314 m long), drilled at Zoigê Basin, eastern Tibetan Plateau. Greigite (SD state) exists along the whole core, and is a main magnetic contributor. Magnetite and hematite are also detected within 160-43 m. NRM directions show a complex record with many apparent changes in inclinations, for which greigite or magnetization acquisition process may be responsible. However, B/M boundary may lie at about 286 m, and Blake Event at 25 m. Within 314-160 m (as well as 43-4.5 m), magnetic intensity (susceptibility k, NRM) may be controlled by redox conditions. Higher TOC content in warm and humid climate favours the formation of greigite, leading to higher k and NRM; while higher carbonate content in dry climate may dilute the concentration of magnetic minerals, resulting in lower magnetic intensity. Within 160-43 m, the low fluctuation of k overlapping on the gradual increasing k background, may be controlled by changes of the redox conditions too. The increasing k background may indicate the changes in concentration of magnetite and hematite related to the uplift of the Plateau.

PALAEOMAGNETIC AND ROCK MAGNETIC PROPERTIES OF A LOESS-PALAEOSOL SEQUENCE IN THE KEY SECTION VIATOVO (N.E. BULGARIA).

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The most complete loess-palaeosol sequence in NE Bulgaria was examined in Viatovo with the aim to built up magnetostratigraphical scheme and to reconstruct palaeoclimatic changes during the Quaternary in this area. The sequence, about 26 meters thick, contains at least seven pedocomplexes and seven loess units overlying red and green clays. The MS signature of the sequence displays highs in the palaeosols and the contrast with the parent loess is similar to what is observed in loess-palaeosol sequences in Asië and Central-Europe. This suggests that the same mechanism is responsable for the soil magnetic enhancement. Oriented samples were taken with a handheld piston corer with split-halve corers which reduces considerably mechanical disturbance during coring. Nevertheless, AMS measurements demonstrate that the magnetic texture changes during coring. The B/M boundary can be located in loess unit L7 and two unidentified normal magnetozones occur in the red clay. An examination in detail of the upper part of the sequence and also of a loess-palaeosol sequence along the Danube near Russe at Km 504 failed to detect the presence of the Blake Event. Thermomagnetic, Mössbauer, hysteresis, IRM and VRM properties were measured in order to identify the nature and magnetic state of the remanence carriers.

MAGNETIC SIGNATURES OF HEINRICH EVENTS SINCE ISOTOPIC STAGE 7 ALONG THE IBERIAN MARGIN.

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A high resolution magnetic study was performed along 2 piston cores collected in 1995 off the Iberian margin (MD952042; 37°47'N, 32m long and MD952040; 40°35'N, 35m long). The sedimentary sequence is composed of homogeneous greys clays. Seven susceptibility peaks occuring during isotope stages (I.S.) 4 to 1 have been identified to Heinrich events (H0 to H6). For HE 2, 4 and 6 the magnetic parameters indicate a larger grain size of the IRD for the Northernmost site (MD952040), suggesting that icebergs reached the margin by the north. H5 is clearly identified by grain-size dependent parameters in contrast with former granulometric analyses (Lebreiro *et al.*, 1997). Major χ peaks also appear during cooling substages 5b and 5d suggesting that ice rafting occured even in I.S.5.
Within I.S. 7, short cold episodes are also expressed by χ peaks characterized by a much weaker amplitude than during the last climatic cycle.

PALAEOCLIMATIC CHANGES IN MAGNETIC SUSCEPTIBILITY RECORD OF THE PERMIAN CLAYS, EAST EUROPEAN PLATE, RUSSIA

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Well logging data of magnetic susceptibility (MS), natural gamma radiation (NGR), SP and electrical resistivity have been employed in studying Permian clay-containing red beds. These parameters display various types of interrelations throughout the section. Thermomagnetic analysis indicates correlation between MS changes and content of γ-Fe_2O_3, α- Fe_2O_3 and Fe_3O_4. Magnetic material of the sediments has been determined to originate from 1) palaeosoil horizons (high content of γ-Fe_2O_3, high values of MS, NGR in clay-containing rocks), 2) remote igneous rocks (Fe_3O_4, association of Fe_3O_4-γ-Fe_2O_3, high content of sand component), 3) Permian sedimentary rocks (hematite, low values of MS, high values of NGR in clay-containing rocks). This model has been used for correlation of "climate optimum" in well sections.

THE PALEO- AND PETROMAGNETIC RECORD IN THE POLISH AND UKRAINIAN LOESS-PALEOSOL SEQUENCES.

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Six loess sections from the Black Sea region, western Ukraine and southern Poland were paleo- and petromagnetically studied. No one reliable paleomagnetic event was found. The values of magnetic susceptibility and saturation remanent magnetization noted in „pure" loess are similar in all sections investigated. The situation is different in the case of pedocomplexes. The susceptibility values noted in all fossil soils from the Black Sea region are tree time higher than observed in the Polish and western Ukrainian pedocomplexes. In the sections from the Black Sea region a very big amount of high susceptible (low coercivity) magnetite grains was also noted in the interstadial soils. Because of this the correlation of petromagnetic curves from the Black Sea sections with oxygen-isotope fluctuations in deep-sea sediments is not so simple as it has been assumed. In all sections studied about seven susceptibility fluctuations were observed in the loesses from interstadial oxygen isotope Stage 3. It seems that these parts of Polish and Ukrainin loess-paleosol sequences are the most promising for further detailed paleoclimatic reconstructions.

A ROCK MAGNETIC RECORD FROM LAMA LAKE - NORTHERN SIBERIA

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A multi-disciplinary German-Russian research project focusses on the reconstruction of the Late Quaternary environmental history of northern Central Siberia. A 10m long sediment core has been recovered from Lama Lake on the Taymyr Peninsula. Palynological investigations revealed a late Pleistocene age (about 17ka) for the core base. The core has been sampled in detail for geochemical and a paleo- and rock magnetic investigation. NRM, ARM, IRM and susceptibility measurements and some low and high-temperature investigations revealed fine grained titanomagnetite as the magnetic phase responsible for the very high NRM intensities. A significant change in magnetomineralogy, grain size as well as Ti-content, can be observed at the Pleistocene/Holocene transistion, reflecting the different sedimentational regimes during the late glacial and the Holocene, respectively.

UPPER PERMIAN CYCLOSTRATIGRAPHY OF EAST RUSSIAN PLATE: ORBITAL PERIODICITY AND PALAEOMAGNETIC DATA

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The Upper Permian of East Russian Plate bear evidence of sedimentation cycles of various orders. Absolute duration of some cycles has been investigated using palaeomagnetic, magnetomineralogical, lythological, and natural gamma-ray intensity methods. Absolute sedimentation rate for Upper Permian clays has been determined through palaeomagnetic study of the spectra of palaeosecular geomagnetic variations. The sedimentation rate depended on periodicity of microlaminations and cycles of solar activity. Magnetomineralogical data on the palaeosoil magnetic components permitted to reconstruct palaeoclimatic conditions. Natural gamma-ray intensity method has been used for the reconstruction of clay component (i.e. relative water depth) changes in well sections. There has been shown the presence of hierarchy of cycles with characteristic periodic ratios which depended on palaeogeographical conditions. The acquired data indicate that the Milankovitch periodicity affected Upper Permian sedimentation process within East Russian Plate.

ROCKMAGNETIC PROPERTIES OF EEMIAN SEDIMENTS FROM LACUSTRINE SECTIONS IN FRANCE: A POSSIBLE LINK TO CLIMATE?

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Climatic varaibility within the last interglacial (Eemian) has been reported from lacustrine sediments from Lac du Bouchet, southern France (Thouveny et al., *Nature*, **371**, 503 - 506, 1994). These sediments were reinvestigated in detail with rockmagnetic methods in order to determine the possible origin of the magnetic susceptibility variations. To support the empirical relation between magnetic susceptibility and climate as inferred in that paper two additional Eemian sequences from french lakes (Lac Saint Front, Ribains maar lake) were studied. Rockmagnetic investigations mainly consisted of analyses of anhysteric and isothermal remanent magnetizations alongside hysteresis measurements carried out on pilotsamples. Results showed evidence for postdepositional magnetite dissolution in Lac du Bouchet, possibly with only minor effects on magnetic susceptibility. Lac Saint Front partly shows a complex behaviour with contradicting results that might be explained by a fine grained magnetite or, possibly, the presence of maghemite. Ribains shows a homogeneous mineralogy without fluctuations in magnetic grain size or magnetic mineralogy. Magnetic susceptibility can thus in all cases be supposed to mainly reflect variations of the detrital (titano-)magnetite input. Nevertheless do sections correlate poorly between the lakes, yielding a dominance of regional effects over a global climatic origin. Thus Lac du Bouchet continues to be the only lake investigated in France so far whose susceptibility signal can tentatively be correlated with greenlandic climatic variations, assuming the latter to be real.

ORBITAL FORCING OF MAGNETIC PROPERTIES: PRELIMINARY RESULTS OF TWO ODP SITES (NORTH ATLANTIC, MEDITERRANEAN)

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Spectral power analysis of magnetic susceptibility data from the ODP sites 963A (Mediterranean) and 981A (North Atlantic) shows clearly the influence of changes of the earth's orbital parameters. The Cobb Mountain event, and the Jaramillo reversal provide a reliable time frame for the pleistocene sediments of both sites.

Assuming a sediment accumulation rate of 94 m/myr for the mediterranean site and 52 m/myr for the north atlantic site, most of the Milancovitch frequencys correspond to maximum values of the power spectrum. Comparing the power spectra of both sites, the influence of the geographical latitude is obvious: While the variation of the susceptibility signal from the north atlantic core is dominated by the obliquity parameters, it is mainly the eccentricity beeing responsible for the changes of the susceptibility of the mediterranean core.

We propose a model in which the insulation is the controlling factor for the concentration of magnetic minerals and hence the magnetic susceptibility: An increased insulation causes a dilution of the magnetic contents due to a higher biogenic productivity. Further more, the magnetic susceptibility is controlled by the varying terrigeneous sediment supply during sea level changes.

CLIMATIC AND OCEANIC TRENDS IN THE LAST CLIMATIC CYCLE VIEWED BY THE ROCK-MAGNETIC SPYGLASS.

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Core MD952042 (IMAGES 101-Iberian margin) 32 m long, contains sediments deposited during the last climatic cycle (isotopic stages 6 to 1). Magnetic susceptibility, Isothermal RM and Sratio spikes characterize IRD layers identified with Heinrich events - in agreement with planktic micro-paleontology (Bouldoire et al. 1996; Cayre et al. 1996) and dolomite contents (Lebreiro et al., 1996). Icebergs drifted down to a latitude of 37°47' not only during H.E. but also during stages 5b and 5d! The «hematite covered grains» (HCG) content -approached by the Hard IRM method -suggest that altered belts contributed to the clastic fraction of some Heinrich layers. The anhysteretic RM mimics the oxygen isotope record (Cayre, 1997) and the organic carbon profiles (Pailler and Bard, unpub.). ARM maxima -marking warm stages- are carried by layers rich in magnetite debries (<1µm) identified by SEM and EDS analyses. Determining the source of this magnetite (continent or oceanic ridge?) is a key for climatic and oceanographic interpretations.

PALEO- AND ROCKMAGNETIC STUDIES OF THE KIRCHRODE CORES (ALBIAN, NORTH-WEST-GERMAN BASIN)

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The paleo- and rockmagnetic investigation of the 371 m thick section of Albian sediments from the research cores Kirchrode I and II (Lower-Saxony-Basin, NW-Germany) mainly follows three goals: (a) to reveal and describe possible linkage between magnetic properties and the variations of the earth's orbital parameters, (b) to search for the existence of reversals of the earth's magnetic field, since the time span represented by the Kirchrode cores is part of the Cretaceous Quite Zone and the existence of reversals has been reported, and (c) to establish a record of the paleointensity of the earth's magnetic field for the Albian. High sedimentation rates of up to 100 m/My allow for temporal resolution of some thousand years. Fundamental interdisciplinary data are already available since the magnetic investigations started during the former Boreal Cretaceous Cycles Project (BCCP). The comparison and correlation of the magnetic data with geochemical, paleontological, and geophysical logging data show that the variations of the magnetic data are independent of lithology and may reflect true variations of the earth's magnetic field.

MAGNETIC CONCENTRATION VARIATIONS IN LOESS SEQUENCES IN CENTRAL ALASKA; REFLECTING CHANGES IN WIND DIRECTIONS AND INTENSITIES ?

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The magnetic signal of the loess/paleosoil sequences in Alaska differs from that in China, the Czech Republic and the Ukraine. In contrast to latter, the Alaskan sequences do not show systematically higher magnetic concentrations in the (paleo)soils, but they do show large concentration variations in the loess intervals themselves (Beget et al., 1990). Hysteresis, frequency dependence of susceptibility and low-temperature measurements indicate that these variations in concentration are accompanied by small, but significant changes in magnetic grain size. Hematite and maghemite were not detected in the loess intervals, suggesting that these magnetic variations are not due to alteration but due to varying wind patterns.

During the presentation we show the results of the rock magnetic and geochemical measurements of the Halfway House and Gold Hill sequences in Central Alaska. We'll discuss whether magnetic changes in the loess intervals can be related to a changing source induced by variations in wind intensity (and directions) during the dry cold glacial periods.

ENVIRONMENTAL MAGNETIC RECORD OF THE LATE PLEISTOCENE TO HOLOCENE TRANSITION AS RECORDED AT SAANICH INLET, VANCOUVER ISLAND, BRITISH COLUMBIA

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The sediments of Saanich Inlet, Vancouver Island, British Columbia, contain an excellent record of the transition from Late Pleistocene glacio-marine muds to Holocene varved deposits. These sediments were sampled in seven holes at two sites during ODP Leg 169S. The deepest hole at each site penetrated approximately 60 meters of Holocene sediment and 50 meters of Late Pleistocene sediment. A complete sequence of u-channel samples was collected from each site. The Late-Pleistocene to Holocene transition is clearly marked by more than a ten-fold decrease in magnetic susceptiblity and in the intensity of anhysteretic and saturation isothermal remanent magnetization. The environmental magnetic changes seen across this boundary in these marine sediments are similar to changes previously reported across similar boundaries found in lacustrine sediments in northern California.

ROCK-MAGNETIC SIGNATURES OF PEDOGENESIS AND CLIMATE VARIABILITY IN SOUTHERN TANZANIA (LAKE MASSOKO) DURING THE LAST 35 kyr.

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Magnetic measurements have been performed on present-day soils, basaltic catchment basin rocks, and cored sediments, as taken out from Lake Massoko (9°20'S, 33°45'E, 770m alt., 41m max. water depth), a ~40 kyr-old maar-lake from the Rungwe volcanic chain. The magnetic concentration proxies point to a significant magnetic enhancement in the soils, and in littoral sediments. Low- and high- temperature experiments suggest that this enhancement results from an increased contribution of 1)SP grains, and 2) SD to MD Ti-substituted Fe-oxides. Like present-day soils, the upper (Holocene) and bottom (>25 kyr BP) sediments have a relatively high magnetic concentration (>1%eq.magnetite), associated with SP to PSD contributions. Changes in magnetic concentration and structure- dependent parameters are associated with changes in pollen, diatom and organic matter assemblages. They indicate short-duration changes in the (P-E) budget, likely through the erosion of littoral sediments during low-stands. In contrast, the sediments deposited in arid conditions, between ~30 and ~6 kyr, point to increased contributions from the catchment. We thus infer a close relationship between pedogenesis and climate dynamics at the precessional scale in the region.

SE34 Rockmagnetism, palaeomagnetism and environmental magnetism

Convener: Hoffmann, V.

05 New challenges in environmental research: magneto-monitoring of anthropic influence to ecosystems

Convener: Scholger, R.
Co-Convener: Rochette, P.

MAGNETIC MAPPING OF SOIL POLLUTION AROUND A GLASS FACTORY OF BRATISLAVA, SLOVAC REPUBLIC

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Recent studies have shown that under certain conditions magnetic susceptibility can be used as a proxy parameter for the detection of higher heavy metals contens in soils. The purpuse of this study is to assess the heavy metals contamination in soils around the glass factory utilizing soil kappametry. Magnetic susceptibility values by field measurements were compared with the results of chemical analysis of soil samples. The highest values of magnetic susceptibility can be easily identified and corespond to the heavy metals contents. The investigation of magnetic susceptibility in soils revealed that its increase is due to immission of air pollutants to SE from glass factory. In this part pollutant resistant trees (pine - Pinus sylvestris) have died due to immission of air glass factory pollutants under influence of prevailing NW winds. There is the highest contamination of heavy metals (especially Cd and Pb) there and the highest values of magnetic susceptibility too.

MAGNETIC SUSCEPTIBILITY AS INDICATOR OF ENVIRONMENTAL POLLUTION OF SOILS IN TALLINN (ESTONIA)

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Low-field magnetic susceptibility (κ) and concentrations of 40 elements were determined for 531 samples collected from topsoils on the territory of the biggest industrial center of Estonia. The study was carried out during a small-scale geochemical mapping and monitoring of soils of Tallinn. The main purpose was to establish the sources of pollution and to study the applicability of magnetic susceptibility measurements for determining geochemical anomalies. Relationship between κ and chemical data was studied by means of correlation and factor analyses. Higher than average κ values were observed in soils on the territory of the phosphorite deposits Maardu. The susceptibility anomaly is caused by particular geological circumstances and can be related to high contents of ferromagnetic minerals in the host rocks. Strong positive correlations of κ with Cr, Pb, Zn and Cu observed in soils from the central part of the city are conditioned by industrial contamination mainly by metal-working factories and by traffic. These heavy metals, known as the most hazardous elements, are easily extracted from the soil in the studied area by plants. In addition to standard geochemical mapping, magnetic susceptibility was successfully applied in determining heavy metal pollution of soils on the city territories.

HEAVY METAL SORPTION ONTO MAGNETITE : CASE STUDY OF CADMIUM

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Over the past 15 years, several rock magnetic studies have evidenced the relationship between magnetic properties and heavy metals contents of materials related with anthropic activities. A lot of pure-chemistry papers pointed out the preferential adsorption of Pb, Zn, Cu, Cr, Cd... on the surface of iron(III) oxi-hydroxides. The purpose of the present experiments is to test the intrinsic relationship between heavy metals adsorption and magnetic properties of the adsorbant. Magnetite has been chosen for its well known magnetic properties, its chemical composition (mixed valence iron oxide) and for its electrochemical characteristics (fast electron delocalization without structural changes). Various studies on chromium or lead sorption onto magnetite have been carried out for 2 years (Peterson *et al.*, 1996; Georgeaud *et al.*, 1997). The chemical ability of magnetite for Cd retention with potential alteration of its magnetic properties will be discussed.

MAGNETIC PROPERTIES AND IRON CYCLING FOR THE LAST 110 YEARS IN THE BALDEGGERSEE, SWITZERLAND

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Iron reacts sensitively to changes in the oxygen conditions of deep water in lakes; therefore, eutrophication affects the internal iron cycling. This study examined the magnetic properties from a freeze core from the Baldeggersee, located on the Swiss Plateau. The core was taken in the deepest part of the lake (66m) in 1993. Varves were used for the detailed dating of the core. Their preservation started in 1885 with the onset of anoxic conditions. The lake became increasingly anoxic and consequently a lake restoration program was initiated in 1982. Mass susceptibility and the intensity of SIRM show a good correlation with the iron content in the sediments. These three parameters show a decrease from 1920 to 1982, after which there is a slight increase in the iron content and magnetic signal. The ferromagnetic mineralogy is constant throughout the core and magnetite was identified from thermomagnetic analysis. Minor fluctuations in the content of superparamagnetic grain sizes appears to be related to summer temeprature conditions. The role of internal iron cycling on magnetic mineralogy will be discussed.

MONITORING OF ANTHROPOGENIC HEAVY METALS ACCUMULATED IN CONTAMINATED SOILS: POTENTIAL OF MAGNETIC PROPERTIES APPROACH ON MULTISOURCE ZONE

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Here, we investigate the relationships between heavy metals and magnetic parameters in soils from the Berre-Fos industrial basin located in southern France. This site is among the largest contributors to anthropogenic emissions in the Mediterranean troposhere. The intensity of saturated anhysteretic and isothermal remanent magnetization (ARMs and IRMs) is clearly correlated to heavy metal concentration. Such correlation is better defined by log(IRMs)+log(ARMs) that equally takes into account ferri- and antiferromagnetism properties. On the other hand, log(IRMs)-log(ARMs) offers an estimate of ferri- and antiferromagnetism respective contribution. The comparison of this parameter to partial IRM (IRM100mt/IRMs) and partial ARM (ARM40mT/ARMs) allows the characterization of industrial sources (including cement works, metallurgy, petrochemical and urban emissions).

SEARCH FOR ATMOSPHERICALLY DEPOSITED FLY-ASH MAGNETITE IN SOILS USING MAGNETIC CHARACTERISTICS

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Soil samples from neighbourhood of a brown-coal power plant were investigated in order to determine the presence of atmospherically deposited magnetite originated from the power-plant fly ash. Magnetic properties of the soil samples and magnetic extracts indicate unique magnetic mineralogy through the whole area in concern. This suggests dominant contribution due to atmospheric deposition of fly-ash magnetite produced by combustion of fossil fuel. Several magnetic parameters (Curie temperature, hysteresis parameters) of soil samples were studied and compared with those of fly ash samples. Good agreement was found between values of remanence coercivity. However, the soil samples did not show increased Curie temperature observed on fly ash samples. Possible reasons for this disagreement will be discussed.

ENVIRONMENTAL MAGNETISM:
Identification of the Onset of Iron Ore Industry in Sweden

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The iron utilized during the Iron Age was always limonite. It took a long time before we understood how to use iron ore (magnetite, hematite). Swedish iron ore factories rapidly spread over Bergslagen (south-central Sweden) in the 16th and 17th centuries. In two cases we know of simple Medieval melting-houses (Lapphyttan and Kalkbro). If early iron ore quarrying and melting existed, this ought to be recorded in the environmental magnetic properties of the sediments. We have analyzed a number of cores downstreams of the Kalkbro melting-house, and a core just outside a very early small quarry. In both cases we record strong peaks in magnetic susceptibility. We associate these peaks with the activity at the melting-house and at the quarry, respectively. In both cases, we are dealing with sediment levels corresponding to early or early-middle Medieval time; i.e. the oldest iron ore utilization known. The exact age is determined by radiocarbon dating of the iron peaks. Our results indicate that this is a poverful tool for the identification of the onset of iron ore utilization in a region.

Magnetic measurements for the detection of roadside pollution: distribution of heavy metal contamination

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Detailed investigations of the roadside pollution due to traffic were performed on an area along the B27 south of the city of Tuebingen (SW Germany). After magnetic susceptibility mapping by using the Bartington field loop (D-sensor) an 11m long profile oriented perpendicular to the road was sampled along a ditch of a depth of 0,5m by (i) pressing inch-sized sample boxes directly in both sides of the ditch and (ii) taking soil samples of a size of 20 x 20 cm and in thicknesses of 5cm. A set of measurements was carried out in order to evaluate horizontal and vertical gradients in the distribution of the following magnetic parameters: susceptibility (χ), hysteresis properties, IRM, backfield-curve (H_{cr}), ARM, thermomagnetic curves (susceptibility vs. high and low-temperature, M_s vs. high temperature). Additional mineralogical studies revealed informations on the (mainly anthropogenic) magnetic phases being responsible for the magnetic signature of the roadside soil. Highly magnetic, magnetite like spherules of anthropogenic origin were detected as the dominating ferri(o)magnetic mineral. The content of certain heavy metals (Pb, Zn, Cd, Cu, Ni, Cr, Fe, Mn) and some organic pollutants was determined to trace the horizontal and vertical distribution in the soil. High correlation coefficients were found between magnetic susceptibility and Pb, Zn, Cd, Cu, weaker correlation with Cr and Ni and nearly anticorrelation with Fe and Mn. This clearly reflects the origin of the respective elements (lithogenic or anthropogenic).

CALIBRATION OF MAGNETIC SUSCEPTIBILITY MEASUREMENTS FOR ENVIRONMENTAL POLLUTION MONITORING

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Precise measurements of specific magnetic susceptibility (χ) of samples are demanded for any kinds of magnetomonitoring. They cannot be done without reliable calibration. The calibration must cover a wide range of values from $\chi = -1 \times 10^{-8}$ un.SI x m^3/kg for water and organic samples to $\chi = 10^{-4}$ un.SI x m^3/kg for technogenic dusts. We use the number of calibrating samples with different volumes, which have been made of high-permeability ferrites (μ >2000) in the form of globes. The calibration is made by value of product κv, where κ-magnetic susceptibility of sample and v - volume . For globe $\kappa = 3 (\mu - 1) / (\mu + 2)$ and when $\mu \to \infty$, $\kappa \to 3$ with relative error $E_\kappa = 3 E\mu / \mu$. Therefore it is enough to measure only v that to know κv. We certified two samples with v = 0.1244 and 0.2215 sm^3 with relative errors ±0.3% and ±0.2%. For calibrating samples with lesser volumes kv have been determined by comparison them with certified ones according to measurements by frequency method. This way of calibration is allowed to use if sensor coil has uniform field in volume equal to the volume of calibrating sample. Use of the precise calibration has permited to determine corrections due to not uniform field in sensor coil of Bridge KLY-1, which are necessary for tests of weakly magnetic liquids.

PARAMETERS AFFECTING THE DISSOLUTION RATE OF MAGNETITE AND MAGHEMITE IN THE CBD EXTRACTION TECHNIQUE

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In environmental magnetism, magnetic parameters are used as 'proxies' to specify processes that have affected soils or sediments. In conjunction with the magnetic parameters, sequential extraction techniques are increasingly used to enhance the interpretative potential of environmental magnetism. In particular, the CBD method is popular. It was originally suggested that the method would only dissolve maghemite but recent studies have shown that fine-grained magnetite can be dissolved as well. The protocol parameters of the CBD-method have been adapted by several workers which makes comparison of the results of different studies difficult. We will present results of an investigation into the influence of parameters like extraction temperature and magnetic mineral concentration on extraction results. Better understanding of the influence of these factors will enable a more meaningful comparison of existing data. An increase in temperature as well as a decrease in magnetic mineral concentration increases the dissolution rate of the samples.

MAGNETIC SUSCEPTIBILITY MONITORING ALONG THE DANUBE RIVER ROMANIAN COURSE; GEOECOLOGICAL SIGNIFICANCES

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New proofs to assess the capacity of the magnetic susceptibility (MS) monitoring to detect some pollutants and their sources are presented.During 1995 research cruise two legs have been performed; profiles consisting of 1-3 sampling stations each have been carried out along the Romanian course of the Danube River, including the main left tributary mouth zones and the distributaries. The highest susceptibility values (k up to 10,465x10^{-6}SIu.) were shown by the bottom sediments sampled in the monitoring stations on the River course between Km 1048.7 and Km 1040. The Danube sands and silts have usually provided k values less than 1000x10^{-6}SIu., even less than 500x10^{-6}SIu. The strong MS anomaly recorded is explained by the influence of known mining/industrial activities in the above mentioned zone. These new results confirm the previous data obtained for the 1992-1994 monitoring phases. The contamination of bottom sediments (k values up to 3253x10^{-6}SIu.) as result of a large industrial activity is again indicated in the upstream zone of the Danube Delta distributaries, particularly downstream of Tulcea (M34), a very important port-town. Also, the MS data confirm the metallic pollution detected for some Danube left tributaries. As a news, two cores collected during the 1995 MS monitoring from the Lake Iron Gates (at Km 969.5 and Km 947.2, respectively) have been investigated, showing similar MS patterns (with a well defined anomalous zone). The result is under consideration for the following geoecological magnetomonitoring phases.

COMPARISON BETWEEN MAGNETIC AND GEOCHEMICAL MAPPING OF SOIL CONTAMINATION IN PRAGUE

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Measurements of magnetic susceptibility of surface soils in public parks of Prague were compared with data on geochemical mapping. Despite rather complex effect of multiple sources of atmospheric pollution, qualitatively good agreement was found between distribution of magnetic susceptibility and concentrations of lead, zinc and cadmium. Various short-range (local) effects were identified, e.g. magnetic signature of paved sidewalks, partial park remediations, etc. Possible links between air borne magnetic minerals and heavy metals in conditions of great urban area are not clear yet and will be discussed.

STANDARDIZATION OF MAGNETIC SUSCEPTIBILITY MEASUREMENTS: CALIBRATION OF LABORATORY AND FIELD INSTRUMENTS

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A number of multidisziplinary case studies have been carried out in Austria to establish cost efficient magnetic field-screening methods for environmental monitoring of pollution of soils and sediments. Laboratory measurements established strong correlations of low field magnetic susceptibility with heavy metal contents. At the same time, comparability of measurements from different instruments and sensors for laboratory and field-use (Bartington MS2, Exploranium KT-9 and Geofyzika KLY-2) has been investigated on selected sets of samples.
Limited depth penetration of the commercial sensors was found to be the most significant source of errors for magnetic field-screening. Results from the cross-calibrations of susceptibility measurements for different instruments will be presented. This attempt for standardization should help to enable a direct comparison of the results from case studies of other groups.

MAGNETIC SUSCEPTIBILITY CALIBRATION OF DANUBE DELTA LAKE SEDIMENTS AS RESULTED FROM THE GEOECOLOGICAL MONITORING, AND THE ENVIRONMENTAL MAGNETIC SIGNATURE

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During 1996 research cruise bottom sediments were collected from both *fluvial delta plain* (16 lakes and 3 channels) and the *marine delta plain* (3 lakes and Sachalin Bay) of the *Danube Delta* (DD) as well as from 3 lakes of the *Razelm-Sinoe lacustrine-lagoonal Complex* (RSLC). The magnetic susceptibility (MS) values (k) are between (-3.2)x10^{-6}SIu. and 497.5x10^{-6}SIu., the interval being very closed to the range characterising the 1995 MS monitoring phase [(-0.9)x10^{-6}SIu.+471.2x10^{-6}SIu.]. Five k classes have been used for MS calibration of lake sediments, indicating good correlations with various deltaic environments, and revealing a case study of anthropic influence to the DD ecosystem. The MS monitoring results confirm the environmental changes induced by the recent human activity interventions (e.g., the digging of a new canal in DD). Besides some *areas under stress* which are again confirmed, a special attention must be given to a lake where the environmental conditions have been degraded since it has been transformed in fishing pool (about 30 years ago). The ability of the MS monitoring (introduced since 1992) to identify *where, when* and *why* the environmental magnetic signature has been changed is commented taking into consideration MS data obtained on bottom sediments having been sampled in DD and RSLC since 1977.

CONTENT OF HEAVY METALS AND MAGNETIC PROPERTIES OF SOILS IN KAZAN, RUSSIA

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Soil samples from industrial areas of Kazan, Russia, have been investigated. Magnetic susceptibility of the samples has been measured by the KL-1 laboratory equipment. Thermomagnetic method has been employed in determination of ferromagnetic minerals and Fe^{2+}/Fe^{3+} ratio. Magnetomineralogical investigations consisted of coercive spectra study and differential thermomagnetic analysis that was used for studying inductive magnetization and various types of remnant magnetization. Atomic adsorption analysis has been used to determine total content of iron and heavy metals.

This research revealed relations between magnetic susceptibility and content of heavy metals for some kinds of soil.

MAGNETIC SUSCEPTIBILITY AND LEAD AND ZINC CONCENTRATION IN FOREST TOPSOIL FROM THE BORDER RANGES OF POLAND, SLOVAKIA AND CZECH REPUBLIK

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The south border of Poland adjoining Slovakia and Czech Republic is 1310 km long. The area is covered mostly by mountain forests. Some industrial districts are situated along the both sides of the border. Thanks to the high smoke-stocks in large plants (mostly power plants) many dusts and aerosols emissions can be transported over the border. In every Polish superforestry situated near the border between Bieszczadzki National Park in the east and Sieniawka in the west, 3-18 soil pits have been excovered and specific magnetic susceptibility (χ) as well as Pb and Zn concentration have been measured. On the base of these datas the transect along the south Polish border has been constructed. The magnetic susceptibility of forest topsoil increases from the east ($40 \times 10^{-8} m^3 kg^{-1}$ in Bieszczadzki NP) to the west ($540 \times 10^{-8} m^3 kg^{-1}$ near Sieniawka) with a maximum in Ustroń and Rybnik Superforestries ($800 \times 10^{-8} m^3 kg^{-1}$). This area is exposed to the influx of pollution from the south (Czech industrial area near Ostrava and from the north (Upper Silesian Industrial Region). In the Opava Mountains χ ranges from 150 to 300 $\times 10^{-8} m^3 kg^{-1}$, and in the Karkonosze Mountain from 80 to 160 $\times 10^{-8} m^3 kg^{-1}$ and increasses towards the west. The concentration of Pb and Zn exhibits the similar spatial distribution but in most samples Pb concentration is higher than Zn. The correlation coefficients between χ and investigated heavy metals ranges from 0.36

EVIDENCE FOR ANTHROPOGENIC INCREASE IN THE FLUX OF FERROMAGNETIC MATERIAL INTO THE CLEAR LAKE BASIN, NORTHERN CALIFORNIA

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Clear Lake in northern California has a shallow basin and high rate of sedimentation. Preliminary paleomagnetic and environmental magnetic data from cores from one of the three sub-basins of the lake indicate that the concentration of ferromagnetic material in the uppermost meter of sediment is more than ten times higher than deeper in the cores. Pb-210 dating suggests this increases coincides with European settlement of the area, an event that was accompanied by large-scale clearing of land and presumably by accelerated erosion of soils developed on volcanic rocks. An alternate hypothesis is that the near surface concentration of ferromagnetic material represents the natural background level and that the lower ferromagnetic concentration seen deeper in the cores is due to bacterial reduction of iron oxides. Additional mineral magnetic studies as well as comparisions with cores from the other two sub-basins will help resolve this question.

MAGNETIC MAPPING OF SOILS IN ALPINE AREA

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The Swiss Federal Institute for Forest, Snow and Landscape has established a national archive of topsoils in the forested areas of Switzerland. Soil samples were taken on a 1 km grid and consist of the upper 5 to 10 cm of soil. The samples were air dried, sieved and stored in plastic containers. A selection of samples from the Cantons of Tessin, Wallis and Graubünden (southern Switzerland) were used to survey regional differences in magnetic properties. The sample area covers 2000 km^2. Different magnetic parameters were used to map magnetic properties over the sampled area. Magnetic extracts were made to identify the sources of the magnetic signal and different chemical analyses are also available, for example of pH, heavy metal content and total organic content. The regional distribution of the magnetic properties depends on different sources of magnetic minerals. The main influence on the magnetic behaviour of the topsoil is pollution on a local scale. High values of mass susceptibility, isothermal remanent magnetisation intensity and coercivity ratios (IRM_{150mT}/IRM_{1000mT}) are found along major roadways - particularly the Gotthard route - industrial areas and cities in general. Soil-profiles to depths of 100 cm have been sampled in different locations in order to identify the lateral distribution of the magnetic and chemical properties.

SE34 Rockmagnetism, palaeomagnetism and environmental magnetism

Convener: Hoffmann, V.

06 Palaeomagnetism and tectonic evolution of the Mediterranean area

Convener: Pares, J.M.
Co-Convener: Dinarès-Turell, J.

BLOCK ROTATIONS AND CONTINENTAL EXTENSION IN THE CENTRAL AEGEAN SEA (TINOS AND MYKONOS ISLANDS)

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We investigated post-12 Ma block rotation in relation to extensional deformation in the western Cyclades. On Tinos, the palaeomagnetic analyses of a swarm of NW-trending dacitic dikes that yield K-Ar ages of 12 Ma reveal 23° vertical-axis clockwise rotation. We assume that the dikes intruded vertical (as they are today) and that no tilt correction is required. The absence of tilting implies that post-12 Ma crustal thinning in the area of Tinos was minor. On Mykonos, a low-angle normal fault dipping 30° to the NE separates a 10 Ma mylonitic granite in the footwall from a series of Miocene molasse sediments in the hangingwall. Published palaeomagnetic results revealed a considerable amount of inclination flattening and 22° clockwise rotation. We bring structural evidence to show that tilting predated vertical-axis rotation and we re-calculate 24° of southward tilt. Counter-tilting leads to steepening of the low angle normal fault to an original dip of ca. 54°. Planar-rotational fault geometry is used to calculate extension of ca. 60%. Our results indicate significant variations in the magnitude of post-12 Ma extension across the Tinos - Mykonos transect, but Moho depth changes only slightly. This indicates decoupling between upper and lower crust and may suggest flow of lower crust material to preserve a smooth Moho. We calculate that vertical-axis rotations increased the N-S dimension of the Cyclades by ca. 31% (25 km).

MILANKOVITCH PERIODICITIES RECORDED IN AN UPPER MIOCENE SEQUENCE FROM CENTRAL APENNINES, ITALY

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An integrated magneto-biostratigraphic study, aiming to define the position of the Tortonian-Messinian boundary, was recently undertaken on a marine terrigenous sequence rich in planktonic forams and calcareous nannofossils from the central Apennines (Italy), close to Pietrasecca village. The proposed correlation with the GPTS, relies with the occurrence of the T-M boundary in the uppermost part of the C3Br.2r polarity Chron, with an age of 7.18 Ma. Other correlations gave rise to unreliable estimates of the sedimentation rate. The investigated interval (30 m thick) shows a marked ciclicity of both the initial low-field magnetic susceptibility (k) and the natural remanent magnetization (NRM) intensity. Power spectra analysis has been then applied on the (k) data in order to determine the presence of periodicities in the record related to the influence of orbital forcing cycles. About 22 m of the previously investigated sequence was resampled by drilling 75 cores at 30 cm intervals. By means of spectral analyses we analyzed the spectrum of (k) signal for a stratigraphic interval 14.10 m thick including the (T-M) boundary. Spectral analysis of the susceptibility data reveals a dominant cyclicity around 19 ka.

TIMING OF NEOGENE TECTONIC EVENTS IN THE CENTRAL MEDITERRANEAN: AN INTEGRATED PALEOMAGNETIC STUDY

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The Central Mediterranean area plays a key role in the interpretation of the geodynamics of the convergence zone between Africa and Eurasia. The evolution of the Tyrrhenian Arc and Hellenic Arc is primarily controlled by this convergence. Hence, the understanding of the tectonic framework of the arc aids in deciphering the underlying geodynamical processes.
Our paleomagnetic studies show that considerable neotectonic rotations took place. The sense of rotations (counter-clockwise or clockwise) are limited to specific domains. With the aid of high-resolution magnetostratigraphy, biostratigraphy and astronomically calibrated polarity time scales we unravelled a precise chronology of tectonic rotations in these domains. Furthermore, we found that tectonic rotations appear to be sudden events, which suggests that the responsible geodynamic processes also occur abruptly. For the Hellenic Arc, we found counter-clockwise rotations on Crete with a Messinian age. Moreover, our results show that the Ionian Island (Zakinthos) started to rotate around 1 Ma, after a period of no rotations of at least 10 Ma. A similar rapid rotation phase was recognised in southern Italy (at 1-0.8 Ma), indicating that this tectonic phase is caused by the same tectonic event, most likely related to processes involving the Apulian platform.

PALEOMAGNETISM OF JURASSIC SEDIMENTS FROM THE FORE-BALKAN AND THE STARA PLANINA RANGES (NW BULGARIA)

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The Fore-Balkan and Stara Planina ranges form the transition between the northernmost part of the Aegean extensional system (Srednogoria) and the margin of the Moesian continent. Samples were collected from 21 sites of Jurassic carbonates and clastic sediments from various structures of different ages throughout a large area. The site mean magnetization directions of the entire region group well after tilt correction is applied (α_{95}: 8.2°), whereas dispersion is considerably larger before tilt correction. The uniformity of this magnetization suggests a pervasive remagnetization just before the last major phase of tectonism, i.e. the neotectonic extensional events that caused the uplift and faulting of the Stara Planina range. The observed area mean magnetization direction (dec/inc: 18°/58°, cf. Oligocene expected direction: 11°/59°) likely reflects the thermal events associated with the active continental margin between the African and Eurasian continents during Oligocene time. Other than in the entire Aegean region including southern Bulgaria, inclination values are not anomalously shallow. Apparently, this transitional area underwent a neotectonic history different from that of the Aegean extensional system to its south.

CORRELATION OF HIGH-RESOLUTION MAGNETOSTRATIGRAPHIC AND MICROPALAEONTOLOGICAL DATA ACROSS THE J/C BOUNDARY STRATA IN BRODNO (W. CARPATHIANS, W. SLOVAKIA) AND THE BOSSO VALLEY (UMBRIA, CENTRAL ITALY)

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As it has been reported during the EGS XXII General Assembly in Vienna in 1997 (cf. Annales Geophysicae, Part I, Suppl. I to Vol. 15, page C 108), high-resolution (HR) magnetostratigraphic and micropalaeontological investigations across the Jurassic/Cretaceous (J/C) boundary strata at Brodno have been almost completed. Additional sampling in 1997 and newly proposed procedure of evaluating HR magnetostratigraphic data contributed to a more precise definition of two reverse subzones located in the normal magnetozones M20 and M19, these two subzones were proposed to be named as "Brodno" and "Kysuca". A section of Maiolica pelagic limestones in the Bosso Valley originally studied by Lowrie and Channell in 1983 was resampled in 1996, 1997; measured data were evaluated for HR magnetostratigraphy and micropalaeontology across the broader section of the J/C boundary strata. Two reverse subzones were found in the normal magnetozones M20 and M19 in identical positions as in the Brodno profile. Detailed palaeontological zonation based on calpionellids was established in relation to the magnetozones and subzones for both the profiles. An improved procedure of evaluating HR magnetostratigraphic data will be presented on the poster.

NEW PALEOMAGNETIC DATA FROM SILURIAN SUCCESSION OF THE DNIESTR BASIN, UKRAINA

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The Silurian deposits from the Dniestr Basin form one of the most complete sections in the world. 44 stratigraphic levels were sampled for paleomagnetic purpose in 8 main outcrops along the Dniestr river. Sampled rocks consist of limestones and dolomites. Samples were submitted to standard stepwise thermal and alternating field demagnetization. Two characteristic components were determined by principal component analysis of thermal demagnetization trajectory. One component of steep, northerly direction was unblocked at temperature of 200-250° C. Second component of shallow southernly direction was unblocked at temperature 450-470° C. In about half samples, third component of intermediate or high coercivity was found by analysing alternating field demagnetization data. Thermomagnetic analysis revealed magnetite as a magnetic carrier of all components. In the upper part of the section the presence of siderite as the potential source of magnetite was suggested. Mean directions obtained for these components are: I=73°, D=338° (α=2.3°); I= -19°, D=203° (α=2.0°); and I=31°, D=215° (α=3.2°). Two first directions suggest that the rocks were remagnetized recently and in Carboniferous time. Third direction gives pole position 351° E and -18 °S, close to the Silurian pole position for Baltica.

REMAGNETISATION AND TECTONIC ANALYSES ON CEVENNES FAULT

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In paleomagnetism applied to tectonics, it is generally essential to find the primary magnetisation in the aim to interpret its deviations as bloc rotations. However, our paleomagnetic study of deformation along Cevennes fault has showed a syntectonic remagnetisation phase which has recorded 80% of the finished deformation. The comparaison of the remagnetisation pole with apparent polar wander path permits to locate this remagnetisation during Eocene or Oligocène, but tectonic structures are consistent with remagnetisation at Eocene. This tectonic interpretation implies an heterogeneous magnetic behaviour related to deformation.

GEODYNAMIC EVOLUTION OF PERMIAN TO NEOGENE ROCK FORMATIONS IN THE W. CARPATHIANS BASED ON SUMMARY OF PREVIOUSLY AND RECENTLY DERIVED PALAEOMAGNETIC DATA

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This study is devoted to a detailed analysis of previously derived palaeomagnetic data from the Permian to the Neogene covering the whole territory of the Western Carpathians and of data recently derived from the E. Jurassic to E. Cretaceous rocks of three tectonic units within the Inner Carpathians. As reported previously in several papers, the palaeomagnetic data indicate marked, predominantly anticlockwise palaeotectonic rotations of large rock complexes, nappes and nappe systems. To judge the possibility of palaeotectonic rotations within smaller areas, virtual pole positions were derived from previously as well as recently derived site means of palaeomagnetic directions. Distribution of all these recalculated and newly derived (virtual) pole positions also suggests significant small-scale palaeotectonic rotations. Dating of previously studied rock formations was recently improved, so that a more precise dependence of palaeodeclination, palaeoinclination and palaeolatitude values of Permian to Neogene rock formations could be derived for the Western Carpathians. Variations in palaeolatitudinal drift from the Permian to the Neogene for the Western Carpathians are similar to those established for other regions in the Tethyan realm (in accordance with results summarized by Van der Voo in 1993). However, a detailed analysis of distribution of virtual pole positions shows some new aspects of interpretation of the origin of palaeotectonic rotations within the Alpine tectonic belt.

A PUZZLING PIECE OF THE PANNONIAN PUZZLE: TERTIARY PALEOMAGNETIC RESULTS FROM THE W PART OF THE TISZA-DACIA MEGAUNIT

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Cretaceous paleomagnetic declinations from the western as well as the eastern parts of the Tisza-Dacia unit (including the South Carpathians) are remarkably uniform, suggesting that the unit must have been involved in a post-Cretaceous large-angle clockwise rotation.
However, Tertiary paleomagnetic results from the Mecsek (Hungary) and the Slavonian Mts. (Croatia) complicate the picture. In the Mecsek, Miocene ignimbrites, bordering the main Mesozoic-Paleozoic body in the north-west, exhibit about 60° counterclockwise rotation. Similarly, counterclockwise rotations were measured in Miocene sedimentary rocks and at an igneous site from the Slavonian Mts. In the main body of the Mecsek, which is the source area of the clockwise rotated Cretaceous directions, the Tertiary rocks, up to 6 Ma in age, exhibit large clockwise rotations.
The regional distribution of the observations with differential rotation suggests that the northern boundary of the rigid Tisza-Dacia unit cannot coincide with the Mid-Hungarian Mobile Zone; we tentatively suggest that the clockwise rotated area may be a thrust of about 5 Ma in age onto a previously counterclockwise rotated region.

PALEOMAGNETISM IN THE NORTHERN APENNINES. ITALY

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A new collection of Late Miocene sediments from the Northern Apennines (NA) has been evaluated with regard to evaluating whether rotations of units in this region are related to opening of the Tyrrhenian sea or to the separation of Corsica/Sardinia (CS) from southern France. The African affinity of paleomagnetic data from the para-autochthonous regions of Adria since Permian times appears to be well established. In contrast, large-scale thrust-related rotations with respect to Adria/Africa (AA) occurred throughout the Apennines during the Cenozoic. Deformation in the Apennines is coeval with (i) the opening of the Balearic sea and the related c.c.w. motion of CS during the Early Miocene, and (ii) the subsequent opening of the Tyhrrenian sea in the Late Miocene and Pliocene. Recent results suggest that at the time of the opening of the Tyhrrenian sea, tectonic rotations in the NA occurred only at the thrust front and far away from the non-rotated Northern Tyhrrenian extensional margin. Therefore, as the opening of the Northern Tyhrrenian sea itself was non-rotational, thrust sheet rotations must be explained by a different mechanism that acted only at the thrust front. On the other hand, it has been proposed recently that the opening of the Balearic sea might have induced rotations in large portions of the Apennine belt. The NA constitute a key region for testing this hypothesis because of the widespread occurrence of sediments (Epiligurian units) deposited before the relative motion between CS and AA. When CS moved c.c.w. off the coast of France, these sediments were presumably "pushed" eastward and rotated c.c.w. above a main boundary thrust onto the AA margin. The new sample collection allows us to test the validity of this hypothesis by allowing us to verify if the end of the "Balearic" rotation predates the onset of the "Tyhrrenian-coeval" rotation observed at the chain front.

PRELIMINARY PALEOMAGNETIC RESULTS ON THE NEOGENE VOLCANISM OF AFYON REGION (CENTRAL ANATOLIA)

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In this study, it was investigated how is tectonic behavior in the Afyon Region between West and Central Anatolia by the paleomagnetic techniques. For this aim, the oriented volcanic rock samples from investigation region of Afyon area which this region is between Central and western Anatolia were collected. The volcanic activity developed in Anatolia (Turkey) during Neogene and Quaternary time represents one of the most understanding examples of arc volcanism related to continental collision. The Neogene and Quaternary volcanism of Central Anatolia represents the central sector of the Anatolian Volcanic Arc related to continental collision between Afro-Arabian and Eurasian plates. It is closely associated with a complex system of tectonic depression related to brittle deformation type which commenced in the late Miocene. General distribution of magnetization directions determined from Cretaceous paleomagnetic data for the Mediterranean plates has been compared on the paleoisocline map that was derived from African and Europeans mean Cretaceous pole positions. Apart from this, the polar wandering curve of paleomagnetic data in Turkey from Permian to Quaternary has also been compared with the African and European polar wandering curves. Comparing the polar wandering curves obtained from Turkey and African paleomagnetic data show that the Turkish plate has moved with African plate in a sense that the rotation rate decreasing from Permian up to present day. This study is a part of Ph.D. study of the first author and is supported by the Research Fund of the University of Istanbul (Project No: T-122/241095

Oblique thrust ramps and spurious apparent rotations on paleomagnetic analysis

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A Spurious apparent rotation (SAR) is the deviation of the paleomagnetic vector (any linear data) obtained after the simple bedding correction when the different tiltings of the rocks took place using axis which are not the bedding strike. The detection and filtering of SAR is an important task that should be considered to avoid incorrect use and interpretation of paleomagnetic data in deformed areas. An oblique ramp of a thrust system may imply a regional rotation (vertical axis rotation) in the surrounding areas due to the differences of shortening between the frontal and the oblique ramps. However a deflection (SAR) associated with these structures could exist depending on the architecture of the thrust system. We analyse the effect of the thrust geometry on the paleomagnetic directions taking into account: a) the angle of the cut off of the footwall, and b) the angle between the frontal and oblique ramps. The modelling has been made for the cases in which the intersection of both ramps (frontal and oblique) is parallel to the transport direction of the thrust. When any of the angles is 0 the apparent rotation is also 0. However if the former angle (cut off angle) differs from 0 there will be an apparent rotation of the sites located at the hangingwall of the oblique ramp. The apparent rotation will depend on the two variables (a & b). We present an example from the Southern Pyrenees in which the apparent rotations found in the oblique ramps of the frontal system spread from -18 to +11. The function that relates the three variables (spurious apparent rotation, cut off angle and frontal-oblique ramp angle) may be used to calculate either of them from the two others. We may calculate transport directions, cut off angles or deduce oblique ramps.

TERTIARY ROTATION OF THE CORSICA-SARDINIA BLOCK : NEW RESULTS FROM SOUTHERN CORSICA VOLCANICS

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A paleomagnetic and magnetic fabric study have been undertaken in three outcrops of Miocene ignimbritic tuffs in Southern Corsica. These discrete volcanic remains (dated by K/Ar at 19 Ma) constitute a previously unknown northern prolongation of the Sardinian volcanic province. Good quality ChRM are retrieved from thermal demagnetizations. Declination values do not evidence any decoupling between Corsica and Sardinia, and record the end of the anticlockwise Tertiary rotation scheme for Sardinia : 17 ± 6 over a total of 35 degrees. Magnetic anisotropy can be used to locate the magma sources but low number of outcrops and complex lineation patterns are strong limitations.

PALEOMAGNETIC TEST FOR CONTINUOUS CRUSTAL DEFORMATION ACROSS THE SOUTHERN DEAD SEA TRANSFORM

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Theoretical models of crustal deformation predict that distributed power law deformation across transform plate boundaries are expressed as (i) counter-clockwise or clockwise rotation across sinistral or dextral faults, respectively, and (ii) diminishing rotation away from the boundary zone as a function of fault length, fault offset and crustal rheology. To test this hypothesis, we measured the paleomagnetic vectors of 373 samples from 54 sites along a 50 km belt westward from the central Dead Sea Transform (DST), where the southern limb of the Syrian Arc fold belt reaches the DST. Fold axes in this belt indeed change their strike continuously away from the DST, from NNE at the plate boundary to ENE at the western extremes of the Syrian Arc fold belt. The sampled rocks are of Lower Cretaceous volcanics, Upper Cretaceous limestones and Middle Miocene combustion metamorphic. The results did not detect any significant rotation about vertical axes, and therefore they do not support the theoretical predictions, although drag in a narrow strip along the fault cannot be ruled out. The paleomagnetic data, therefore, suggest that the orientation of fold axes of the Syrian Arc are original and not the result of rotation about vertical axes as means of continuous crustal deformation.

STRUCTURAL AND PALEOMAGNETIC DATA FROM THE AMANTEA BASIN (CALABRIA, ITALY): INSIGHTS ON THE GEOMETRY OF THE LATE MIOCENE TYRRHENIAN RIFT

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We report on new structural, magnetic anisotropy, and paleomagnetic data obtained in the Amantea basin, located in the Tyrrhenian extensional margin of the Calabrian Arc. The basin is formed by a Tortonian-Messinian sequence which is transgressive over the Alpine Calabrian units. Microstructural analyses extensively carried out in the Neogene sediments show that the onset of the clastic sequence was accompanied by strong synsedimentary tectonics. Due to this late Miocene activity, the basin was cut by NNE-SSW normal faults which define a N120° direction of extension. Anisotropy of Magnetic Susceptibility analyses carried out in 13 different sites show a well defined magnetic foliation parallel to the local bedding planes and a distinct magnetic lineation trending N115° in average. This lineation reflects the stretching direction responsible for the foundering of the basin and the synsedimentary tectonics. Paleomagnetism of the 13 sites shows that Messinian clays are dominated by greigite and/or magnetite, while the Tortonian sediments are characterized by an association of magnetite and hematite. Reliable site-mean directions from 8 sites pass both a reversal and fold test. These directions document that the Amantea basin has undergone about 18° clockwise rotation. This implies that the late Tortonian Tyrrhenian rift basin, to date partly preserved in the Amantea basin, was bounded and controlled by roughly N-S normal faults. We conclude that the early E-W spreading of the Tyrrhenian Sea took place as a consequence of the eastward Calabrian drift.

TECTONIC HISTORY OF THE DOLERITES FROM THE REGGANE BASIN (ALGERIA) AS EVIDENCED BY THE PALEOMAGNETISM

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The doleritic basalts which outcrop in the folded Paleozoic Series of the Reggane Bassin are generally interpreted as the result of a volcanism having acted during the first stages of the opening of the Atlantic ocean in the lower Jurassic. These Dolerites constitute either thin units interlayered within the upper Paleozoic strata, or dikes cross-cutting the whole Paleozoic series. A paleomagnetic study of these Dolerites was undertaken to clarify the following questions : Are the folded units basaltic flows erupted during the upper Paleozoic or sills intruded in the lower Jurassic within the Paleozoic ? When did the two phases of deformation occur relative to the acquisition of the magnetization ? The mean characteristic magnetization obtained after AF and thermal cleaning of 92 samples out of 11 sites (D=330° I=28°) and corresponding PGV : λ=60°N φ=254 A95=7) is consistent with a Jurassic age, supporting the hypothesis of intrusive bodies. A progressive unfolding of the sites allows to quantify the following scenario : the Dolerites were intruded in a Series which had been already gently tilted in the late Paleozoic : the folding increased after the Dolerite emplacement and prior to the Cretaceous.

PRELIMINARY RESULTS OF THE PALAEOMAGNETIC STUDY OF A NAMURIAN FORMATION FROM THE AHNET BASIN (SAHARAN CRATON, ALGERIA).

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In the Aïn Chebbi area (Ahnet Basin, Algeria), a recent palaeomagnetic sampling has been carried out in the different levels of the Namurian formation. Although, the analysis is still in progress, its preliminary results show (in addition of a total recent remagnetization) the existence, of two components. The first one (D= 325.0 I= 23.9 k=72 α_{95}= 9.1;in stratigraphic coordinates) is very close to that determined in the jurassic doleritic sills (Smith et al, in preparation), which outcrop in the studied area. Its corresponding V.G.P.(53.4 S, 74.2 E) is in good agreement with the african previous ones of Jurassic age. this component is then a probably jurassic remagnetization. The second one determined by both remagnetization circles analysis and Characteristic Remanent Magnetization (ChRM), has the following direction (in stratigraphic coordinates): D= 140.0 I= 26.6 k= 51 α_{95}= 7.9 . Its corresponding V.G.P. (33.8 S, 49.0 E) is close to the previous upper carboniferous african poles determined in the neighbouring areas. This component is then probably of primary origin. Further analysis will allow to precise these new results and would certainly improve the Upper Paleozic part of the African Apparent Polar Wander Path.

SE35 Archaeology and archaeomagnetism

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01 Archaeological prospection

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COMBINED GPR AND SEISMIC INVESTIGATIONS IN URBAN AREA (LECCE - ITALY).

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Integrated geophysical investigations, electromagnetic (GPR) and seismic (refraction method), were carried out in urban area to locate and reconstruct buried archaeological structures. A GSSI SIR-2 radar unit with monostatic 100 MHz and 500 MHz antennas collected radar data in a grid covering just a little less than one hectare of ground surface; a Geometrics Strataview Seismograph (12-channel) was used for the seismic survey. The interpretation of data gave a global geological characterization of the area and the geophysical study provided informations about the location and extension of some buried structures. Post-excavation comparison confirmed geophysical expectation.

INTEGRATING MAGNETIC MEASUREMENTS WITH ARCHAEOLOGICAL DATA

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Many types of human activity affect the magnetic properties of the geological materials on which they occur. The integration of measurements of magnetic susceptibility, viscosity, gradiometry and archaeomagnetic data; with other archaeological information, allows detailed interpretation of deposits and their origins.

The potential of the close integration of magnetic measurements with ongoing archaeological excavation is illustrated by discussion of the investigation of a multiperiod settlement mound at Scatness, Shetland. Particular emphasis is placed on the use of magnetic remanence, viscosity and susceptibility to determine date and function of hearths and burnt areas; employing susceptibility, in combination with chemical and environmental evidence, to determine source material and formation processes of middens on the site, and combining environmental and soil micromorphological evidence with susceptibility to detect and characterise anthropogenic enhancement of soils

The examples demonstrate that, when combined with other archaeological information, the evidence of human activity retained in magnetic properties can prove a valuable tool for archaeological interpretation.

CESIUM MAGNETOMETRY FOR LARGE AREA PROSPECTION AT QANTIR-PIRAMESSE (EGYPT)

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At Qantir-Piramesse in the Nile Delta a large area magnetic prospection was undertaken in October 1997 using two Scintrex SM4G-Special Cesium magnetometers in duo-sensor configuration. The site covering about 30 km^2 was identified as the ancient capital of Ramses II. The aim of the survey project is the city map of Piramesse, mainly built by mudbrick architecture. Therefore not only a high spatial resolution in sampling (at least 25 x 50 cm) is required but also ultrahigh sensitivity for the detection of mudbrick structures in the Nile mud. Furthermore fast methods are required regarding the extent of the area. A comparison in 1996 between cesium and fluxgate-magnetometry and resistivity demonstrated that mudbrick architecture at a deeper soil horizon is only detectable by cesium magnetometry. The mudbrick structures, and also sand foundations of missing stone buildings show up as negative magnetic anomalies. Mineral magnetic measurements in the laboratory on soils and mudbricks explain the magnetic anomalies. The magnetogram of 25 hectares already gives an impression of the splendor of Ramsess City with temple- and living-buildings, workshops, streets, canals and also wide open areas.

MAGNETIC PROSPECTING AND DATING OF ANCIENT POTTERY KILNS

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Detailed magnetic measurements of unexcavated ceramic kilns can reveal much about their location, shape, and internal construction. There are more than 26 medieval pottery production centers known in mountainous Crimea, but only several of them were partly excavated. A special investigetion program is devoted to the revealling and detail mapping of these centers. Further analysis of these measurements can allow estimates of the depth of the kiln and its total mass. The direction of the magnetization of the kiln can also be estimated, and this may allow the approximate date of the kiln to be determined. Excavation is costly in time and money; it is also destructive. Geophysical exploration can aid archaeology by describing underground features as closely as possible; this will allow the locations for excavations to be carefully selected by the archaeologist. The experiment with dating by analysis of magnetic anomaly is focused on two kilns in Crimea. Before excavation, the outline and the general internal construction of this kiln were revealed by a magnetic map. This map was made with closely-spaced measurements with the magnetic sensor directly on the surface of the soil; this allowed the very high resolution image of the kiln to be created. These magnetic measurements were also analyzed to determine the total magnetic moment of the kiln and also the center of its magnetization. Three different methods were tested in order to estimate the inclination and declination of the vector of total magnetization. Archaeomagnetic dating of kilns has, in the past, required kilns to be excavated. Oriented samples of the kiln are extracted and laboratory measurements determine the orientation of the magnetization (Eighmy and Sternberg 1990). This experiment is directed toward the possibility of estimating the magnetic orientation without the need for excavation. The further development of the method and dating of other Crimean pottery kilns was possible thanks to CRDF grant.

ARCHAEOLOGICAL-GEOPHYSICAL INVESTIGATION OF THE ANCIENT SITES ON THE RURAL TERRITORY OF BOSPORUS CIMMERIAN

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Geophysical investigation in Eastern Crimea were carried out by the joint expedition of Saint Petersburg State University and the Institute of Archaeology RAS in 1982-1997. Last years these investigation was possible thanks to the grants of Russian Human Foundation (RGNF) and Federal Program "Integration". The main working method is magnetic prospection with archaeological excavations of the limited plots on chosen areas. In antiquity the coastal line (30 kms) of the Sea of Azov to the north of the town Kertch was densely populated with a Graeco-Barbaric population: there are several dozen settlements and cemeteries, and traces of field boundaries are clearly seen. At these sites, anomalies from the limestone walls of buildings were expected to seldom exceed 2 - 6 nT. Complete interpretation of the images is facilitated by the use of a physical - archaeological model of the objects. Comparisons between the maps of calculated and measured magnetic anomalies makes it possible to locate buried objects which, in ancient times, were subject to fire; these objects could be stones or fire places. Owing to magnetic mapping of the sites, it is possible to determine the types of settlement, the main design elements, and the characteristics of the building techniques which is necessary for an identification of a site as an antique Greek or a local barbaric settlement. Additionally, other archaeological problems, such as a determination of the boundaries of the settlements, the dynamics and growth of their defensive structures, and their types of building materials, were solved. The objective of this work is the composition of a review of geophysical maps and interpretation plans of the region which would served for the purpose of scientific historical investigations as well as for the establishing of protected archaeological zones.

A DISCUSSION ON THE RESOLUTION OF TWO DIMENSIONAL RESISTIVITY MODELLING

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Theoretical resistivity profiles corresponding to a subsurface resistivity structure probed via assortment of arrays have been calculated using the finite difference method. Some of the assumptions implicit within the calculation are illustrated by examining the effect of the precise relative positions of an electrode array and a buried future. The responses for the Wenner, pole-pole, and dipole-dipole arrays were carried out by using the horizontal profiling technique. Four different possible relative array/feature positions modelled with the finite difference method. The variability of the calculated anomalies shows that any modelling approach will need to be fine and flexible if an accurate iterative inversion of field data is desired. In other words, the block size of the finite difference mesh should be equal to 1/4 (0.25 by 0.25 units) of the minimum electrode spacing.

DIRECT INTERPRETATION OF COMBINED SOUNDING-PROFILING DATA

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In this work one-dimensional direct interpretation of vertical electrical sounding is employed for two-dimensional combined sounding-profiling data (pseudosections) interpretation for some of the shallow surveying objectives. The technique is simple and straightforward and is applicable to determine the depth of bedrock and mapping its relief or overburden layers such as top soil, and to determine geometry of a land-slide. The direct interpretation of combined sounding-profiling data will be given with a numerical modelling, analogue tank modelling, and a field example to demonstrate how to map bedrock relief.

Three-dimensional reconstruction of archaeological features using geomagnetic data

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There is a still increasing risk of damage for many archaeological sites because of heavy agricultural utilization and building activities. Since excavations are limited because of limited financial resources, a non-destructive investigation and 3-D reconstruction of archaeological features using geophysical methods becomes more important. Estimations of the approximate shape and position of the features may help the archaeologist to plan and adapt excavations according to the actual situation.

A robust and stable inversion algorithm for 3-D reconstruction of different archaeological features from surface magnetic data was developed. This procedure works in two steps. In a first step the mean magnetization direction and the top soil depth will be estimated under the assumption of a simplified model. During the second step the shape of the features is estimated automatically. The algorithm was tested on different synthetic data sets and applied to magnetic data from two different places in Saxony, a bronze age settlement at Zwenckau, near Leipzig and a fortification system at Seidewitz, near Torgau.

Top soil conditions and detectability of archaeological objects

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The detectability of archaeological features, such as filled pits or ring ditch systems, depends on the magnetic properties of the filling, and thus, on soil properties, material transport mechanisms and chemical conditions in the subsoil.

A number of large-scale investigation projects in connection with open coast mines and the construction of pipelines around Leipzig lead to the discovery of different settlements, ranging from neolithic times to late iron age. Several archaeological features from different sites were sampled and investigated with regard to their magnetic properties, e.g. susceptibility measurements, x-ray diffractometry, paleomagnetic measurement.

A correlation between magnetic properties and topography as well as soil types was found. A weak correlation between the age of the archaeological feature and the magnetic properties could be established.

AN APPROACH ON 3D ARCHAEOLOGICAL INTERPRETATION OF GROUND PENETRATING RADAR DATA

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The application of GPR in archaeological prospection is still under discussion between archaeologists and involved geophysicists. A new approach is presented to include GPR data in standard interpretation methods of archaeological geophysics. In the Roman town Carnuntum a georadar survey was carried out to aid the interpretation of a representative building recovered by a former resistivity and magnetic prospection. A pulse EKKO 1000 was used to investigate the building which has an extension of 63.5 m x 44 m using a high spatial resolution of 0.5 m x 0.1 m. The image representations of the time-slices are archaeologically interpreted in a GIS considering the interpretation of resistivity and magnetics. The various interpretation slices are then combined to a 3D archaeological interpretation model.

ARCHAEOLOGICAL INTERPRETATION OF MAGNETIC DATA

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Particular archaeologic sites containing distinct artifacts were considered by magnetic measurements. This paper deals with the main problems that generally arise during the application of magnetic intensity to archaeological investigations. Specific difficulties include lateral variations of magnetic susceptibilities of top soil and near surface rocks, shallow heterogeneities, or equipment and reduction errors. In addition, an example of a magnetic survey for archaeological exploration at a part of Tell Basta historical site, Zagazig, Egypt is presented.

The observed data were distorted. However, reduction, filtering, correlation and modelling of the field measurements help in improving the signal-to-noise ratio and better definition and resolution of composite anomalies.

Within the surveyed area, the study indicates that 1) The significance of numerical processing techniques in improvement of the meaningful anomaly-to-noise ratio and 2) The presence of some shallow anomalies (0.5-3m depth) of archaeological interest. The revealed depths to the different discontinuities agree fairly well with the archaeological evidences excavated later.

LE PRINCIPE DE LA RESOLUTION DU PROBLEME INVERSE GEOELECROMAGNETIQUE POUR LES OBJETS ARCHEOLOGIQUES EN 3 DIMENSIONS

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La resolution du probleme inverse dans la prospection electrique et magnetique c'est la partie la plus importante pour l'interpretation des donnees. Le but essentiel de la geophisique-archeologique -la reconstruction des planes des fondaments des batiments anciens. La detalisation de ses traveaux est beaucoup plus haute que celle en geologie. Notre methode utilise les unitees des dipoles comme les briques pour construire les modeles geoelectriques et magnetiques des objets. Cette approximation a le nombre infinie de variants de la resolution, si n'ajouter pas les conditions specifiques-phisiques. Dans la prospection electrique l'unitee de dipoles equivalents aus objets doit avoir la concordence interieure: chaque dipole de cette unitee doit etre collineaire avec le champ electrique sommaire des issues du current et du champ de tout les autres dipoles. Dans la prospection magnetique chaque dipole doit etre collineaire avec le champ magnetique de la Terre. Du point de vue mathematique ca signifie la nèssecitee de minimiser la difference des mesures et du champ de l'unitee des dipoles avec les conditions quadratiques (problemes electrique), ou pas negatives (en magnetisme). Le programme pour l'ordinateur qui realise cette idee dans la prospection magnetique a donnee les resultats suffisents.

MAGNETIC, ELECTRIC, RADIOACTIVITY AND THERMAL INFRARED IMAGING FOR INTERPRÉTATION OF ARCHAEOLOGICAL DEPOSITS STRATIGRAPHY.

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In the northern part of France, the so called "dark-earth" archaeological deposits, commonly lay directly upon relic Roman floor levels and continue upwards into overlaying Medieval deposits. These sediments with a thickness of 0.3 to 1 meter contain very few archaeological features and no stratigraphy can usually be observed within the deposits. Consequently, the origin and significance of dark-earth are difficult to explain. We aimed at finding on a cross-section of dark-earth, a spatial organisation defining a stratigraphy by the use geophysical methods. We studied 3 sections on 2 French archaeological sites (Paris, and Château-Thierry) containing those enigmatic deposits. We conducted susceptibility, radioactivity, electrical resistivity measurements using pole-pole and wenner devices, and finally infrared thermography in both infrared and near infrared spectrum. Except for the last method, measurements were achieved point by point on the cross sections. The different maps show discontinuities in the cross-sections corresponding to biological perturbations and archaeological structures.

GPS AND GIS AS RESEARCH TOOLS IN ARCHAEOLOGY FOR DETERMINING FORMER ENVIRONMENTAL CONDITIONS

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The position of archaeological finds were determined with GPS on 3 small hills in the Hungarian Lowland bordered by the Duna and Rába rivers and the Hanság area. The properties and age of finds, the chemical and physical characteristics of soil layers such as pH, CaCO3 content, organic matter content, texture, phosphate content and depth of water table level at the location of find were determined and collected by GIS. The location of finds of different ages and the properties of soil layers followed a tendency. The settlements on the small hills outstanding from the surrounding area and regularly disturbed with floods have located always near to the bank of water since Neolithic age. The finds of late Neolithic age located (111,0 m) near to the present water table level (110,5m). The finds of middle copper age were somewhat higher (111,5m), and 112,5 m was the height of the settlement in the bronze age. Concluding, when the settlement was on the lower part of the hill the climate was dry, when it was on the higher part of the hill the climate was cool and rainy. Comparison of the chemical and physical properties of the layers of disturbed and undisturbed soil profiles also contributes to the reconstruction of former environmental conditions.

ANALYSIS OF THE CHANGE IN THE VELOCITY OF THE ELECTROMAGNETIC WAVES WITH THE WATER CONTENT.

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Ground Penetrating Radar (GPR), allows a high resolution in archaeological research. The studies of high resolution with electromagnetic waves require a good knowledgement of the wave speed into the analyzed media. We have performed some GPR experiences in order to observe the wave velocity variation during its propagation in different conditions of humidity in the same materials. We have been able to detect important variation of the wave speed when the water content is increased. This variation is caused by the change of the electromagnetics properties of the materials. The analysis of the arrival time of the reflected waves in the surface where the material properties change, allows us to calculate the wave velocity in the saturated and in the unsaturated marble rock. With this velocity, the effective electromagnetic constants of the marble (saturated and unsaturated) have been obtained. These electromagnetic constants have a value of about 5 in the unsaturated materials, and a high value (about 12) in the saturated marble. The analyzed marble layer was placed over a layer of concrete. The electromagnetic effective constant obtained in the non-saturated area was about 8, while the constant in the saturated area was about 17.

PROCESSING AND INVERSION OF MAGNETIC GRADIENT DATA IN ARCHAEOLOGICAL PROSPECTING

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Magnetic gradient prospecting is a powerful means of mapping the distribution and extent of archaeological remnants in the shallow subsurface. With increasingly sensitive magnetometers, bodies of limited spatial extent and low magnetization can be detected and mapped. For example, modern Cesium magnetometers now provide sampling rates as high as 0.1s and resolution as good as ~0.01nT. Employing Cesium magnetometers, two people recently collected magnetic gradient data over an area of 220 m x 60m. Only two days were required to record the entire data set using a grid spacing of 0.25 m x 0.25 m. The anomalies at the site were expected to be caused by moderately magnetized topsoil deposited in ditches and ancient pit-houses. In order to extract the maximum information possible from these high-resolution data, refined processing and imaging techniques were applied. Non-linear colouring-schemes (e.g. histogram-equalization) and 2-dimensional filtering (e.g. reduction to the pole, 2nd vertical derivative) were applied successfully. The resultant images improved markedly the visibility of anomalies and contributed to a better understanding of the underlying structures. To extract information about the depth extent and shape of the archaeological structures, an inversion algorithm that converts magnetic gradiometer data into subsurface structural models was developed. Tests on synthetic data provided key data on the performance characteristics (e.g. resolution and error limits) of the inversion algorithm. A subset of the Unterstammheim magnetic gradient data set was successfully inverted to show the shape and extent of a mediaeval pit-house.

INTERACTIVE INVERSE MODELLING OF MAGNETIC DIPOLE CLUSTERS AND ARCHAEOMETRY OF IRON AGE SLAGS

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Geological structures are usually so complex that a simple dipole approximation is semi-quantitative at best. One exception is formed by the slag bodies from small scale iron production in Central, Easter, and Northern Europe in the period 200 BC – 1600 AD. These bodies give rise to very regular dipole anomalies of amplitudes about 100 nT just above ground. Thus, they are easy to detect, but the slag bodies occur in densely spaced groups so that anomalies overlap, and slag fragments dislocated by ploughing act as added noise. Significant secular variation occurred during this period, so the direction of magnetization is indicative of the slag age.
We present a procedure for a complete modelling of position and magnetization direction of individual slag bodies that occur in groups. Our implementation consists of a conventional linearized inversion module and an interactive partial inversion front-end, where the user controls the number of dipoles, their starting/prior parameters, and the number of dipole parameters to release. This implementation is robust, flexible and easy to use for non-specialists in inverse theory.

TECHNIQUES APPLIED TO MAGNETIC INVESTIGATION OF IRON-PRODUCTION SITES IN CENTRAL EUROPE

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Different techniques for investigation of old iron-production sites in SW Jutland (Denmark) and Lusatia (Germany) are presented. They include geomagnetic surveying for localizing the iron-production centres, micromagnetic measurements for studying the fine structure of the magnetic field in the vicinity of iron-slag bodies as well as data inversion and palaeomagnetic investigation techniques for age determination purposes. The applied techniques were adapted to the geological situation and the site formation processes, e.g. the utilization of the area under study during the last century. Specific adaptations are described. It is also shown how archaeological excavations may be planned and monitored by the magnetic surveying. As presented, the inversion results appear to give reasonable age estimates for the slag bodies after a magnetic refraction correction is applied. Finally, a short description of developed software for data processing and inversion is included.

APPLICATION OF DETAILED MAGNETIC METHODS DURING ARCHAEOLOGICAL EXCAVATIONS IN BOHEMIA

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Some of geophysical methods it is possible to use in time of open archaeaological excavation. The rapid increase of rescue archaeological excavations in 1990s gave in Bohemia opportunity to test possibilities of use of magnetic methods in such a not traditional and less optimal conditions. The results for example showed that by gradient magnetometric survey of area near the edge of brown coal mine without removed subsurface layers we could identify stoney fillings of graves on Late Bronze Age graveyard as on northbohemian site Konobrze. Another example from North Bohemia shows application of detailed magnetometric survey of excavated prehistoric tomb near Cernoucek. Various amplitudes of intensity of magnetic field here separate dark soil filling inside of rectangular ditch and stoney filling of central grave (massive neovulcanic blocks). Interesting results brought detailed surveys of excavated archaeological features by measuring of magnetic susceptibility on cleaned surface in situ by kappameter. The results in cenralbohemian site Tisice inside of open Iron Age graves identified by maximum not only places with metal jewels but also by minimum separated the relict of wooden coffin. Experimental measuring of sample of excavated polycultural settled area near Tisice in Central Bohemia showed that this method could be used in case of homogenous nonmagnetic material of excavated surface for reidentification of small not vell visible features (pits) which could make then together relict of lagrer regular features (house).

A PURELY GEOPHYSICAL DISCOVERY OF AN ARCHAEOLOGICAL IRON AGE SITE AT THE WESTERN SHORE OF LAKE BAIKAL

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When carrying out TEM survey on the Chernorud site at the western shore of Lake Baikal slowly decaying transients were measured over metamorphic poorly conductive cristalline. Laboratory studies on parent rock and soil samples included: 1) microscopic examination; 2) TEM measurements; 3) X-ray diffraction, hysteresis, and thermomagnetic analyses. It turned out that the anomalous transients were caused by the relaxation of magnetization of single-domain near-surface particles the origin of which, for a long time, remained a mystery. In 1996, we fortuned upon a gopher's burrow. Among the soil thrown out of the burrow we found slugs and charcoal, which suggested an ancient metallurgical activity. The slugs' examination has revealed that they are electrically nonconductive and consist predominately of a silica matrix with dispersed within it ultrafine magnetite and iron particles. Being placed into a small coil, the slugs produced slowly decaying transients caused by magnetic viscosity phenomenon. Magnetic survey carried out over an area in the vicinity of the slugs' find has revealed positive magnetic field anomalies with amplitude of about 20-50 nT. At our request, an excavation was made this summer by Dr. A. Kharinskiy, an archaeologist from the Irkutsk University, which resulted in discovery of slugs, charcoal, porous iron, baked clays, some artifacts, and - at a depth of about 0.8m - remains of a bloomery furnace.

RELATIONSHIP BETWEEN ANTHROPISATION AND THE MAGNETIC PROPERTIES OF SOILS : A case study in the archaeological site of Roissy-en-France

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Magnetic prospecting of archaeological sites depends strongly on the susceptibility k of the upper layer of the soil and on the abundance of its ferrimagnetic minerals. These minerals may be of biologic origin, usually bacteriologic, or human origin, by firing. To characterise and identify different ferrimagnetic minerals in several archaeological soils, we have performed thermomagnetic and hysteresis parameters measurements on a set of samples. The pedological and micromorphological analyses are associated to this study to determine the relationship between the pedological and human activities (ferruginisation and anthropic objects) and the magnetic parameters.

Maghemite was identified by the thermomagnetic curves as the main magnetic mineral in archaeological sediments. The link between ferruginisation and high magnetic susceptibility is not clear. However, the correlation between the ratio of susceptibility on saturation magnetisation χ/Js and the abundance of anthropic objects is quite good. In association with magnetic susceptibility and remanent coercive field. we can give an estimation of anthropisation of sediments. The thermomagnetic curves and the comparison between natural heated sediment and the anthropogenic sediments enable an estimation of the temperature of the heating of furnace for example.

Geophysical prospections of archaeological sites in Brandenburg

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During the last few years archaeologists collected a lot of knowledge about several sites in Brandenburg by aerial photography. In addition we carried out geophysical prospectings to get more information about interior structures, depth ranges and physical properties. So we investigated several circular ditch systems in different geological areas. In the south of Brandenburg there is a Neolithic ditch system, which has significant magnetic anomalies of about 2-5 nT/m (Fluxgategradiometer), so that we could detect not only the main structures but also some palisades. In the eastern part of Brandenburg there are two sites supposed also with Neolithic origin. One of them can partly been well prospected with help of magnetic, but there are some parts which can be seen only in air photographs. The third site is covered by ortstein (cemented sandstone with oxides), so that magnetic investigations are not possible . Because of the higher conductivity correlated with greater humidity within a ditch system such structures can be prospected with help of electromagnetic. This correlation leads to the fact that former ditches can be prospected not only outside civilisation but also within a city. With direct current method we estimated the location of some Slave ditches and also younger ditches within the city Potsdam.

ESTIMATION OF SYSTEMATIC ERRORS OF 3-COMPONENT GEOMAGNETIC DATA USING THE ABIC-MINIMIZATION METHOD

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The geomagnetic anomalies measured are often effected by the systematic errors caused by various factors, for example,drifts in magnetometer reading, interference of magnetic field from the carried devices, and so on. The correction of those systematic errors by the modified ABIC-minimization method. The original ABIC-minimization method [1994,Murata] assumes that the optimum correction values of the systematic errors will lead to a smooth geomagnetic anomaly. And the trade-off between misfit residual and surface roughness is determined to minimize the ABIC (Akaike's Baysian information criterion). In this study, 3-component geomagnetic data has been used which is obtained from the 3-component fluxgate gradiometer. So, the magnetostatic relation between each component of the magnetic field is concidered in this correction process.

2D AND 3D INTERPRETATION TECHNIQUES OF GPR DATA IN ARCHAEOLOGICAL PROSPECTION

Lorra, S.; Stümpel, H. and Thomsen, D.

The use of high resolution geophysical methods for archaeological prospecting has increased rapidly in the last 15 years. The Archaeological working group located at the Institute of Geophysics of the University of Kiel (Germany) has been involved in complete project solutions over the last 10 years. Our experience covers the work starting with the data acquisition using a combination of different geophysical methods all the way to the appropriate presentation of the results.

On the technical side we have made several in house developments for magnetic surveys including the design of a portable fluxgate gradiometer array, a multichannel data logger and software package for data management and processing. For precise mapping of archaeological structures located in the subsurface mainly magnetics and resistivity have been used. Ground penetrating radar (GPR) was rarely taken into account because of the large amount of data and the time consuming interpretation. In the past, the main disadvantage was that the interpretation of 2D-GPR-sections was depending to a high degree on the experience of the geophysicist and therefore was too much relying on subjective decisions. Moreover GPR often fails in clayey soil conditions. Three case histories will be given showing an appropriate way of GPR-data processing and interpretation. Consequently 2D-data acquisition using different frequencies and a narrow profile segmentation as well as 3D-processing techniques were developed to optimise the analysis of GPR-sections and finally make use of the high resolution capability of GPR.

A HIGH DENSITY RESISTIVITY SURVEY AND A EXPERIMENTAL MEASUREMENT OF TEMPERATURES OF THE GROUND ON HIRUI-OTSUKA MOUNDED TOMB IN OGAKI, JAPAN

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The Hirui-Otuka mounded tomb located in Ogaki-city, Gifu Prefecture, Japan, dated back to the late 4th century AD. The resistivity survey was carried out in order to acquire information about its central burial. A 48-electrodes cable with 50cm spacing was used. The Wenner configuration was adopted in this surveying; electrode spacing was changed by 0.5m from 1.0m to 4.0m, and the measurement point was shifted at intervals of 0.5m. It took only 11 minutes to get 241 readings per line. Total 34 lines were measured, consequently 23.5m by 16.5m area was surveyed. Some resistivity anomalies were observed: one of them seemed to be a central burial. A measurement of temperatures of the ground was carried out in order to acquire information about relation between the organization of under-ground and the temperatures of the ground. Sensors sheathed by a stainless steel pipe 60cm long filled with oil, was inserted 50cm in depth under the ground. The measurement was gone on continuously for 38 hours, automatically. At the measurement point over the central burial, a large phase delay was observed.

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MICROGRAVIMETRIC INVESTIGATIONS IN THE VALLEYS OF THE KINGS AND QUEENS, LUXOR, EGYPT

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No doubt that Egypt is a country extraordinarily rich in ancient sites with unique monuments documenting its famous history over thousands of years. It is obvious that not all of the archaeological secrets have been discovered. One of these areas is Luxor with the Valley of the Kings and the Valley of the Queens, Upper Egypt. Experimental microgravimetric investigations were performed in 1996 and 1997 in order to test the possibility of detecting well-known, but hidden unknown tombs with corridors just as well. On several lines the gravity was measured by two LaCoste&Romberg gravimeters D188 and G1043. The attention was focused at calculating all necessary corrections and reductions of the data. With respect to very complicated topography, a combined method of removing the relief impact was applied. By modelling we also estimated the effects of known entrances and corridors of the tombs. In most cases this processing sequence resulted in the elimination of registered anomalies. The remaining indications were analysed and explained by geological phenomena on one side, and by possible buried archaeological objects on the other side. Further study is necessary to prove the results and concentrate on promising sites.

GEOPHYSICAL SUPPORT IN LARGE SCALE ARCHAEOLOGICAL PROSPECTIONS, RECENT CASE-STUDIES AND RESEARCH.

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Archaeological prospections over large areas prove to be very difficult, due to the nature of the archaeological evidence. Archaeological evidence can be small in size and small in contrast to the suroundings.
Recent research about the use of electromagnetic measurements, GIS, thermal infra-red scanning and laser-altimetry prove that combined information aids the interpretation of the archaeology over large areas.
Some case studies from the wet-lands in The Netherlands and from Northern France will be presented.

IMPROVEMENTS IN HIGH RESOLUTION ARCHAEOLOGICAL MAGNETOMETRY

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An automatic positioning and recording wheeled caesium gradiometer device with 0.1 nT sensitivity was used for archaeological prospection for over 10 years in Austria. A recently developed new multi-sensor caesium magnetometer device MEP750 with 0.001 nT sensitivity is presented here. The first applications and tests prove the high reliability of the system used in 0.125 x 0.5 m standard raster. Two sites were remeasured to compare the new device and its variabilities of configuration to the former system. Multi-sensor arrays make it possible to derive multi-image information from the data for subsequent archaeological interpretation. The first survey with the new system recovered longhouses from the Early Neolithic about 7000 BP.

QUANTIFICATION OF SUPERPARAMAGNETISM WITHIN LEWISIAN ARCHAEOLOGICAL SOILS

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Archaeological soils are magnetically interesting as they contain very small superparamagnetic iron oxide grains, which are associated with burning. An unmixing algorithm based on room temperature hysteresis loop data has been developed. The algorithm allows the quantification of different domain states, including superparamagnetism, of various magnetic minerals, and also paramagnetism and diamagnetism. As well as estimating the superparamagnetic concentration, the algorithm can also estimate the superparamagnetic grain size.
Room temperature hysteresis loops have been measured on a range of material types, including hearths, pit fills and middens from a multi-period settlement in the dune system to the east of Bostadh beach, Great Bernera, Lewis. Subsequent unmixing of the hysteresis loop data has revealed superparamagnetism to be the dominant domain state in the majority of soils. The unmixing results have also revealed a restricted estimated superparamagnetic grain size distribution of 75 to 90 Å.

GEOMAGNETIC PROSPECTION OF AN EARLY NEOLTIHIC SETTLEMENT IN ASPARN / LOWER AUSTRIA

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During the last five years a large site from the Early Neolithic (about 7000 BP) was surveyed with different caesium magnetometer devices covering an area of over 20 ha. The site is fortified by ditches with varying state of preservation. Inside the fortification the ground plan of typical longhouses could be lined out by magnetics. The remains of the wall foundation trenches are obvious and even the roof bearing posts are detectable. The site was prospected using a wheeled caesium gradiometer with 0.1 nT sensitivity as well as a multi-sensor MEP750 caesium magnetometer with 0.001 nT sensitivity and allows comparison of the two devices applied in a 0.25 x 0.5 and 0.125 x 0.5 m standard raster.

Analysis of GPR pulse response from experimental and archaeological test sites.

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GPR has been applied in many studies including: ground water investigations, identification of buried objects, soil mapping, civil engineering investigations. This method has been also used in reconnaissance surveying for non-destructive archaeological investigations.
Often in the surveyed area, the presence of disrupted soil and/or correlated localized noise can mask the signals due to the expected bodies. The study of the reflected characteristics of buried targets, under controlled test conditions, can help to understand the GPR system capabilities.
Response from simple buried bodies (cylinder and sphere) are investigated in the test pit of C.N.R. and in the archaeological sites containing cavities and portion of walls. The measurements were carried out using the bistatic OYO YI, R2 system equipped with 600 MHz antenna and SIR System 10A equipped with two 100 and 900 MHz antenna.
Parallel, perpendicular and cross-polarized antenna configuration were employed during the acquisition. The experimental and field results are elaborated and analyzed with the aim to characterize the reflected signals.

THE ANCIENT LION HARBOUR OF MILETUS: GEOPHYSICAL INVESTIGATIONS

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The ancient Miletus was one of the largest and most prosperous cities on the coast of Asia Minor. It was situated at the golf of Latmos which is today silted up by the sedimentation of the Menderes river. Since Miletus was the center of Ionian trade, the ground plans of the harbour buildings and basins are of special importance for the architectonic reconstruction of the city. In order to define constraints for this reconstruction, we investigated the so-called Lion Harbour, a former bay of 150m*300m extent, by a combination of different geophysical methods and drilling. Remnants of mole foundations were found by magnetic mapping. The morphology of the former harbour basin was determined by 3D shear wave seismics and DC resistivity sounding. The seismic results were calibrated by drilling and borehole seismic measurements. Caused by the high shear wave velocity contrast between basement and sedimentary fill, and by the strong curvature of the basin cross-section we observed curious wave phenomena which were verified by FD seismic modelling.

GEOPHYSICS FOR ARCHAEOLOGICAL PURPOSES ON THE TERRITORY OF KAZAN KREMLIN, KAZAN, RUSSIA

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Kazan Kremlin is the historical monument of the 16-18 centuries AD. Major ancient buildings here are the Suyumbeki Tower, Spasskaya Tower, Blagoveschensky Cathedral, and 8 preserved watch-towers which are connected by the Kremlin stone wall. Since 1994, when Kazan Kremlin became State Museum, intensive archaeological excavations are accompanied by forestalling geophysics comprising high-precision gravimetric survey, electromagnetic sounding, georadar measurements and some other methods. Geophysical investigations permitted to contour sites of preserved remains of ancient buildings: Spaso-Preobrazhensky Cathedral, Church of Kiprian and Ustinia, Bell Tower of Blagoveschensky Cathedral, Holy Gate, wall of the Cannon Smelting House. Gravimetric data indicated remains of ancient stone constructions south of Blagoveschensky Cathedral, stone wall and the destroyed kiln near former Military School that was confirmed in the course of the following excavations. There have been located supposed remains of ancient buildings in the cultural layer recommended for further excavations. Electromagnetic sounding indicated the cultural layer to be 1 to 7 m thick resulting in vertical total conductivity sections with lateral inhomogeneities supposedly associated with the remains of ancient buildings.

ADVANCED MAGNETOMETRY FOR THE CHARACTERISATION OF EARLY IRON-WORKING SITES

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In order to gain further understanding of early iron-working sites geophysical techniques can be used for a non-destructive investigation. It was the aim of this study to evaluate the information that can be obtained through advanced magnetometer surveys. Three sites in Yorkshire (England) were selected for surveying: (i) a previously excavated shaft furnace was reburied in non-magnetic sand; (ii) the site of a known furnace that was excavated subsequent to the geophysical examination and (iii) a site of intense iron working that was already well characterised through non-destructive methods. The three sites were surveyed with (a) conventional fluxgate gradiometers (FM36); (b) a three-component fluxgate gradiometer and (c) a Caesium total field gradiometer with additional base-station. The combination of data from these different sources provided insight into the organisation of the sites. Results will be presented that highlight the merits of the individual techniques and demonstrate the benefit of data integration (this research was funded by the NERC).

SE35 Archaeology and archaeomagnetism

Convener: Fassbinder, J.
Co-Convener: Hoffmann, V.

02 Archaeomagnetism and secular variations

Convener: Kovacheva, M.
Co-Convener: Chauvin, A.

TWO NEW ARCHAEOMAGNETIC RECORDS FROM SOUTH KOREA

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Thirteen samples were collected from several remains of prehistoric fireplaces of the Bronze Age located at Pyeongra-ri, Boryeong-gun, Chungnam in May 1995. The samples consists of pinkish gray baked earth with low magnetic susceptibilities. Excluding three scattered samples, the natural remnant magnetization directions yield a mean direction of $D = 1.0/I = 59.5$ $[\kappa = 36.6, \alpha_{95} = 8.1]$. Although the data appears to be somewhat scattered, the mean direction seems to be reliable. Charred grains (barley, wheat, and beans), charcoal, dolmens, and stoneware were excavated from the ancient housing sites. The age of ca.1500 B.C. was estimated from these ancient artifacts. Twenty-three samples were also collected in June 1995 from the draft floor of an old kiln of 'Noborigama' type located in the area not far from the above prehistoric remains. Archaeologically, the estimated age of the kiln is ca. 14 century; however, the mean direction ($D = 352.2$, $I = 52.7$) of the samples is very similar to the present earth field.

NEW ARCHAEOMAGNETIC STUDIES IN CHINA AND THEIR USE IN ELUCIDATING GEOMAGNETIC SECULAR VARIATIONS

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The compilation of archaeomagnetic data for secular variation curves is necessarily time-consuming and piecemeal. However, regions such as Shaanxi Province in China have great potential, with many well-documented, independently dated fired remains of all periods.
This paper reports on archaeomagnetic and mineral magnetic studies of known-age samples of fired structures and sediments from key archaeological sites in the vicinity of Xi'an. The fired materials are shown to retain a stable record of the direction of the past geomagnetic field, which compares well with previous studies and contributes to an understanding of secular variation in the region. However, discrepancies with documented observations of the field are noted.
Methods of smoothing the data are then presented, demonstrating that geomagnetic change can be delineated by relatively few, well-dated samples. Comparisons are drawn with similar treatment of analogous UK archaeomagnetic data in periods where the measurements of direction available are widely and unevenly distributed through time.

DATING STONE BUILDINGS AND ROCK MOVEMENTS BY VISCOUS REMAGNETIZATION

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The magnetic mineralogy of certain rocks permits a remagnetization of selected grains over time scales similar to the relaxation times of their remanences. When disturbed, they may come to rest in a new orientation with respect to the Earth's field, either by the action of man or naturally, as for example in a land-slide. At that time the appropriate grains in the ferromagnetic grain population start to progressively remagnetize parallel to the current geomagnetic field. As time passes the remagnetization approaches saturation and it may be calibrated using historically dated buildings as an absolute dating technique or, more generally, used as a relative dating technique. In tests in Britain the technique has a resolution of 25 years for structures 1800 years old but becomes increasingly less precise with age. The method may also reveal multiple reorientations of rock samples, e.g., during historical reconstructions, or landlside phenomenon.

DRIFT OF "MAIN' PERIOD OF THE GEOMAGNETIC FIELDD INTENSITY.

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Theanalysis oflongrows of archaeointensityforthesix territoriesinlongitudinalsector 27-136 degrees E(Bulgaria, Caucasus, Middle Asia, lake Baikal region, China and Japan) allowsto conclude,that"main" periodofarchaeointensity
variations may be estimated as about 8000 years.Examination ofphases of this variationfor different regionsshowed, that thereistheeastwarddrift,which velosity is 0.25 degree peryear. Amplitude of8000-yearsvariation is about 10 A/m and changed from6 A/m for China up to 12 A/m for Middle Asia and Georgia.The highestdeflecxionofphasesfrom linear longitudinal dependence is for regionoflake Baikal and China.Itis probably connected withwild limits of dating of archaeologicalmaterialsand forlack ofnumber of determinations. From the another sidetheremaybe the latitudinal dependence ofthis variation,as lake Baikal ison 14 degreesnorthly and Chinaon 6 degrees southly of the rest territories (about 40 degrees N).

200-yrs VARIATION OF THE PALEOINTENSITY.

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The comparision of the paleointensity change during the last 4000 years for the Caucasus and Central Asia allows to reveal the variation with period about 200 years. Its amplitude increases from 2 mkT in c.XVII B.C. to 12 mkT in c.VII B.C. In c.VII B.C. the sharp decrease of paleointensity took place. After that the amplitude of the variation was stable; its mean values was about 4 mkT. This effect is more distinct for Central Asia; for the Caucasus it is smoothed. This phenomenon preceed Etrussia excursion.

ARCHAEOMAGNETIC DATING IN MACEDONIAN KILNS (N. GREECE)

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Archaeomagnetic investigations at several sites in N. Greece are in progress since 1995. Twelve of them, mostly kilns, have been sampled by standard techniques and directional measurements for eight kilns have already been reported (EGS XXII, 1997). The date range is classical to post Byzantine (300 BC-1500 AD). We present here further studies on this collection which include : a) Lowrie - Fuller tests, thermomagnetic and IRM analysis and an intensity result for site DI which allowed the dating of a glass kiln at 820-870 AD. This result was confirmed by the finding of contemporary coins. b) The anomalous behaviour of site AL which did not allow any calculation of a mean direction is attributed to the considerable anisotropy of the material. c) By using reference curves for Bulgaria - after converting I values - we have been able to give dating estimations for sites EV (100-300 BC), LM (200-400 AD) and LC (500-620 AD) , all confirmed by archaeologists. d) In Louloudia (LC, LM) detailed susceptibility measurements on samples from cross-sections have defined the most intense levels of human activity . e) Finally directional data from the four new kilns are in progress.

Geomagnetic evidence for the time-selecting concept of Ancient Chinese health promotion

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The time-selecting concept is deeply embedded in the Chinese culture especially in the field of Chinese medicine, acupuncture, and chigong--an interdisciplinary health promotion method includes physical, mental, and breathing training (similar to Yoga or meditation which has been known by the western world). We determined the effect of geomagnetic variations on the time-selecting concept by examining a statistical result of the most favored periods and the characteristic of geomagnetic variation in those periods. We searched the literature related to the health promotion in archives starting from 14th century to recent times. Our investigation shows that the hours between 11 p.m. and 7 a.m. (four ancient Chinese time periods) are the significantly favored periods for practicing chigong and other health promotion exercises and that 1 a.m. to 5 a.m. (two ancient Chinese time periods) are the most favored periods. We analyzed the year-round relative occurrence frequencies of the daily geomagnetic stable periods and correlated the geomagnetic data with the health promotion period. The result indicates that the ancient Chinese health promotion periods coincide with the geomagnetic stable period of a day. This result may shed some light on the hypothesis that a stable geomagnetic dipole field is good for human health.

INTERLABORATORY COMPARISON OF ARCHAEO-INTENSITY STUDY AND ANISOTROPY EFFECT

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Archaeointensity determinations over the sister specimens using the Thellier type experiment performed in two different laboratories are compared. These laboratories are the Laboratory of Internal Geophysics. Univ.of Rennes1 and the Palaeomagnetic lab. of the Geophysical Institute, Sofia. This comparison showed a very good consistency between the results obtained in two laboratories. The often insufficient burning of the used materials can cause a great inter-site scatter of the palaeointensity results which acquires additional rock-magnetic studies. Two methods are applied to estimate the possible magnetic anisotropy effect on the intensity results: through TRM anisotropy tensors (Rennes lab.) and through week IRM anisotropy tensors (Sofia lab.). Both have shown a negligible effect of magnetic anisotropy in the materials from the prehistoric ovens. The applicability of the nondestructive method of evaluation of the anisotropy effect through calculation of the anisotropy tensor of induced week IRM is discussed.

COMPARAISON OF THREE SMOOTHING ALGORITHMS PERFORMED ON THE HEIGHT MILLENNIUM ARCHEOLOGICAL DATA FROM BULGARIA.

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More than the final drawing of the height millennium variation curve of the Terrestrial Magnetic Field (TMF) in Sofia (Bulgaria), the topic of this study is to discuss some peculiarities of the raw data and the meaning of statistical parameters in use in Sofia and in other laboratories. Analysis of the most time extensive archaeological data set recently updated by Kovacheva (1997), offers the opportunity to use more than 150 fire places where all the three components of the TMF (Inclination I, Declination D, Intensity F) are provided. These data come from a small geographic area, have a wide range of measurement and dating precision, and provide a good example of the treatment of extracted sub-populations. Comparison with results of other archaeological data sets shows clearly the importance of sampling accuracy and sample size and/or cutting. When the three different smoothings are made, simple to sophisticated, the mean curves show a good agreement. The directional values obtained with the best precision factor are close to the mean curve, although the intensity data do not agree as closely. This last observation seems to show that the two dispersions don't have the same probabilistic origin.

SECULAR GEOMAGNETIC VARIATIONS AND DATING OF THE ARCHAEOLOGICAL REMAINS

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Recent archaeological excavations in NE Bulgaria discovered the next big Thracian tomb, constructed by stones in the hill No30 of the complex Sborjanovo. The tomb is dated 4-3c. BC. In front of the tomb's entrance the remains of weakly burnt earth have been found. In the very close proximity, the remains of large fireplaces (eshairae), situated in the tumulis enbankment (small hill No28) were found. We have sampled the remains of the burnt clay and an extenssive archaeomagnetic study has been undertaken. The archaeologist's supposition. without having fount sufficient archaeological evidences, was that these remains are of the same time period (4-3c. BC). Our results compared with the previously established geomagnetic master curves show that the archaeological dating is not acceptable. The results from a similar fireplace from the same complex (hill No35) are also discussed in the light of non-agreement between the geomagnetic results and archaeological dating.

ASSESSMENT OF THE MOVING WINDOW METHOD OF SECULAR VARIATION CURVE CONSTRUCTION: ANALYSIS OF THE BLINMAN PROBLEM

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Conveners: Dr. Mary Kovacheva, Dr. Annick Chauvin
Preference for oral presentation
EGS Support Award applied for: Keith Runcorn Travel Award

Archaeomagnetic dates are generally determined by comparing the direction of the thermoremanent magnetization (TRM) of burnt archaeological features such as hearths, kilns, and habitation floors to a reference curve of the geomagnetic secular change for the particular regions of the collected feature. The precision and accuracy of the dates depend, in part, on the precision and accuracy of the reference curve, and the quality of the reference curve depends, in turn, on the data used to produce the curve. Continuing efforts to improve the quality of the U. S. Southwest archaeomagnetic reference curve have led to the addition of 23 high quality, independently dated prehistoric virtual geomagnetic poles to the current U. S. Southwest data set. They have also resulted in an assessment of Sternberg's (1982) statistical methods employed in constructing the curve. Certain problems with the currently accepted moving window method of curve construction have been recognized (Eighmy et al. 1993). Cox and Blinman (1996) identify one such problem involving the way the curve is drawn in areas where it loops back on itself. Due to the averaging statistics employed, poles that plot on the inside of the curve tend to systematically pull the curve to the inside, generating tighter loops and kinks in the master curve. In order to fully address this problem, steps have to be taken to first prove its existence, and then quantitatively assess its magnitude. Running historically known pole positions through the curve building program and comparing the resulting curve to a "hand-drawn" one is one method of addressing this problem. Another is to use the curve building program to build a hypothetical curve from known points that simulates the shape of SWCV595, and to then move the points around in order to determine how their relative positions affect the overall shape of the curve.

BAYESIAN APPROACH USING PENALIZED MAXIMUM LIKELIHOOD TO SMOOTHING TIME SERIES CARRING ERRORS BOTH ON TIME AND MEASURE : CONSEQUENCES FOR ARCHAEOMAGNETISM

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We will present a statistical tool which allows to transform the measurements (inclination, declination or intensity) of the components of the TMF into a mean reference curve versus time, with a confidence interval, and which takes into account both errors on the magnetic measures and the errors on the dates assigned to the reference sites. Usually, the date of the last heating for a baked clay is indicated as a time interval with uniform probability. We will show how the bayesian approach which is based on the « penalized roughness » in the context of non-parametric regression, allows to remove the difficulties due to the moving average technique currently used in the elaboration of smoothed curves. On the other hand, we will propose an improvement of the transformation process of a magnetic result into a date. We suggest to use an algorithm very close to the one used for the dendrochronological calibration of radiocarbon dates. In this way, it becomes possible to obtain a chronological solution (simple or multiple) as a probability function, which can be summarized by an interval of date defined for a fixed level confidence. Thus, this date interval will depend on the measurement errors and on the quality of the secular variation reference curve available.

FINE-TUNING THE PALAEOSECULAR VARIATION RECORD FROM FISH LAKE, OREGON, WITH ARCHAEOMAGNETIC RESULTS FROM THE NEARBY LOST DUNES ARCHAEOLOGICAL SITE

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The paleomagnetic record from Fish Lake in eastern Oregon has been proposed as a master curve for Holocene secular variation in the Pacific Northwest of North America. The Lost Dunes archaeological site, also located in eastern Oregon, has a radiocarbon age of 300±100 yr.bp. An archaeomagnetic study of six hearths from that site has yielded a paleomagnetic direction that is not concordant with the corresponding point on the Fish Lake curve. However, removal of a 5° inclination correction that was originally applied to the Fish Lake curve produces concordance in the paleomagnetic direction. The need for the inclination correction was inferred from a comparison of the paleomagnetic direction of the 6,900 year-old Mazama tephra, found near the base of the Fish Lake core, with the paleomagnetic results from lava flows erupted at the same time as the Mazama tephra. The new archaeomagnetic results suggest that the paleomagnetic record from Fish Lake has experienced progressive, downcore inclination-shallowing due to compaction.

HISTORIC MELTING PLACES; SOURCE OF PALEOFIELD INFORMATION

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During the last years, several bronce age melting places were investigated in order to test the possibility of paleomagnetic age dating as well as investigating the paleointensity of the earth field. The usual material used for these investigations belongs to the oven wall or the slag from the last melting process. Refraction effects as well as dislocalized fragments of the oven caused usually a large scatter in the paleomagnetic dataset. Because of this problems, the suitability of the burned soil in the basement of the roast beds were tested. In these roastbeds the ore becomes oxydized by burning off the sulfur at temperatures of about 600 to 900°C. The temperatures at the bottom is estimated by looking at the colour. The change from black to red is usually found to be at about 250°C. The thickness of this layer varies between 5 and 15 cm. The minerals found in this layer are geothite and haematite, minor magnetite. The scatter of the paleomagnetic data is dominated by the grainsize of the soil respectively the geometric accuracy of the individual sample.The paleointensity was estimated by using the techniques of Thellier&Thellier ,Shaw and Kono and found to be sufficient in the temperature range between 250 and 400°C.

MICROWAVE ARCHAEOINTENSITY RESULTS FROM EGYPTIAN CERAMICS.

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Ceramic sherds have been collected from 50 Egyptian sites ranging in age from 1000 AD to 3000 BC. Several ceramic samples from each site have been analysed using an 8GHz microwave cavity to demagnetise the NRM and to give a TRM in a modified version of the Thellier experiment. Samples were very small cores (5mm diameter and 3mm long) and were analysed on an automated system incorporating a SQUID magnetometer. Each sample was individually corrected for cooling rate before calculating the archaeointensity value. The archaeointensity results will be presented and compared to existing results from the Mediterranean region.

POWER-SPECTRAL ANALYSIS OF ARCHEOMAGNETIC AND SECULAR VARIATIONS

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Power spectral analyses of the dipole moment of the earth's magnetic field inferred from ocean sediment cores of Meynadier et al. and archeomagnetic data from Kovacheva from time scales of 100 yr to 4 Myr have been carried out. The power spectrum is proportional to $1/f$ where f is the frequency. These analyses compliment previous work which has established a $1/f^2$ spectrum for variations at time scales less than 100 yr. These results suggests that smoothing of data can be misleading: geomagnetic variations are significant on all time scales. Power spectral analyses of inclination and declination inferred from lake sediments from time scales of 10 yr to 30 kyr have also been performed. The spectra are constant above time scales of 3 kyr, proportional to $1/f^2$ from time scales of 500 yr to 3 kyr, and constant again below time scales of 500 yr. The 3 kyr time scale is associated with the decay time of the quadrupole moment. We test the hypothesis that reversals are the result of variations in dipole intensity with a $1/f$ spectrum which occasionally are large enough to cross the zero intensity value. Synthetic binormal time series with a $1/f$ power spectrum representing variations in the earth's dipole moment are constructed. Synthetic reversals from these time series exhibit statistics in good agreement with the reversal record.

Updated Geomagnetic Dipole for the period 0-12,000 Years

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An analysis has been made of all archaeointensity data for the past 12,000 years. There are 3,243 results from different areas of the world covering the past 12,000 years. 2,203 from the European region, 1040 from the rest of the world. Data analysed in the present study is almost three times that used by McElhinny and Senanayake 15 years ago. Although there is no significant difference between the updated global model and the previous one, the result for non-european region has been improved. By comparing results from different region of the world, we can better define the behaviour of the geomagnetic field.

A GERMAN ARCHAEOMAGNETIC SECULAR VARIATION CURVE FROM 1000 TO 1800 AD

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An archaeomagnetic secular variation curve for Germany will be presented based on recent paleomagnetic measurements carried out on archaeological sites in Germany and a collection of published archaeodirections from the surrounding countries. The German archaeological sites have been investigated by using standard paleomagnetic and rock magnetic methods. Samples have been taken mainly from kilns which were preserved from the epoch of the Romans or from the epochs between the middle age and the 18th century.
Following the authors for the French or British archaeomagnetic master curves an area of similar size is used to obtain an averaged secular variation curve for Germany. This area ranges from 3 to 15°E in longitude and 47.5 to 57.5°N in latitude. Therefore also a part of the French data and furthermore published archaeodirections from the Netherlands, Denmark, and Belgium can be included in the data set for the curve. Geographical and age distribution of the data set is very uneven but for the time interval 1000 to 1800 AD at least 5 data points per 50 year interval can be used to calculate an average curve. This curve clearly deviates from the French or British master curves. It is clear that much more work is neccessary to obtain a data set which will establish a master curve for Germany.

COMPARISON BETWEEN REMANENT MAGNETIZATIONS OF VESUVIUS PYROCLASTITES OF 79 A.D. AND POMPEI MURAL PAINTINGS

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Many mural paintings survived the Vesuvius 79 A.D. eruption that destroyed Pompei and Ercolano. Red colour specimens were collected in four buildings and investigated according to the usual palaeomagnetic techniques. Notwithstanding the very low magnetization intensity, in most specimens stepwise alternate field demagnetization isolated a stable characteristic component and the mean directions were statistically significant at three sites. They are consistent with the palaeomagnetic directions from the pyroclastic flow that buried both cities, which were derived from literature data and two new sampling sites (D = 351, I = 58.5, alpha-95 = 1.7°). These results show that pictorial remanent magnetization carried by red coloured paintings is a reliable record of the Earth's magnetic field.

SE36 Potential fields in geodesy, geophysics and geology (co-sponsored by G)

Convener: Jacoby, W.R.
Co-Conveners: Braitenberg, C.; Grafarend, E.W.

ON THE STRUCTURE OF THE MAGNETIC FIELD AT THE CORE-MANTLE BOUNDARY

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The calculation of the coupling torques between core and mantle (core-mantle coupling) requires the knowledge of the magnetic field at the core-mantle boundary. This field is calculated by means of a regularizing algorithm of the (unstable) continuation, which generates the non-harmonic downward continuation in the case of spherically symmetric electrical conductivity in the lower mantle. The outer boundary values at the earth's surface are taken from the coefficient functions $g_{nm}(t), h_{nm}(t)$ of the standard spherical harmonic expansion for a time interval covering the last one hundred years. The magnetic field at the core-mantle boundary depends on the assumed mantle conductivity and the time structure of the boundary values. We present predictions of the core-mantle boundary field up to degree and order 5 for different assumptions.

ANALYSIS OF GRAVITY DATA WITH 3-D HILBERT TRANSFORMATION

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Three-Dimensional Hilbert Transformation (3-D H.T.) can be used to estimate the structural parameters with the use of derivatives in x, y, z direction of the potential field data. Up to now, 3-D H.T. has successfully applied to synthetic magnetic data. 2-D H.T. technique is of a limited applicability because of the implicit assumption that the source is linear and 2-D body oriented at right angles to the profile direction. However, 3-D H.T. has no limits in applicability and it can be used for all 3-D anomalies. To explore the applicability of 3-D H.T. to the gravity potential problems, the method was also applied to several synthetic gravity data. A priori known boundaries and corners of the synthetic data were successfully determined. Dips of a fault and an inclined dike model which are not possible to determine with 2-D H.T., can be obtained with 3-D H.T. procedures. Finally, g_{zz} components of gravity potential anomalies can also be derived through the 3-D H.T. besides the procedures of the Laplace Differential Equation which has been used up to now. 3-D H.T. was also be applied to gravity data of Western Turkey Region to find out the tectonic lines. The most prominent structural and morphological feature of the western Turkey extensional province are E-W trending normal active fault system which bounds the grabens. They may sole into sub-horizontal zones in the uppermost lower crust and therefore have a listrict geometry.

PALAEOROTATION AND CHANGES IN TIME OF THE EARTH'S INTERNAL STRUCTURE

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There is observational and theoretical evidence that the Earth's despinning rate was much smaller — by factor of about 5 — in the Proterozoic than in the Phanerozoic. According to Varga et al. [*J. Geodynamics*, **25** (1998), 61–84], the available fossil clock data suggest that the length of the day (LOD) was increasing on the average about 3.5 s per million years during the Proterozoic, i.e. roughly between 2500 and 640 million years ago. During the Phanerozoic (between 640 million years ago and the present epoch) the average increase of LOD was about 18 s per million years. Thus, tidal despinning was much less important in the remote past when the Moon was closer to the Earth and, therefore, should have raised larger tides. The most likely explanation of this paradoxical result is that the Proterozoic oceanic tidal dissipation rates were very small compared to what they were on the mean during the Phanerozoic and what they are today. Nevertheless, reordering of mass through diffusion, fractionation and sedimentation processes may have played a role as well. Our work is more particularly concerned with core formation and core evolution as a possible factor of speeding up the Earth's rotation throughout the Proterozoic.

APPLICATION OF THE HILBERT TRANSFORM AND POWER SPECTRA IN THE POTANTIAL FIELDS

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In this study, the model parameters of the structures with known analytical expressions were estimated by using power spectra and Hilbert Transform in Gravity and SP methods. The power spectra expressions of a sphere, cylinder, horizontal semi-infinite sheet, dike, fault models in the Gravity method and an inclined thin rod, horizontal cylinder models in the Spmethod were obtained by taking analytical Fourier and Hartley Transforms. By examing both analytic and discrete power spectrums of the models, we observed that the slope of the spectra was related with the model depth and that the amplitude of the spectra was related with other parameters such as density, mass and thickness. Thus, in the power spectra applications of the potantial field data, the depth estimation can be achieved by the expression slope=-2h. Also, the Hilbert Transform was used to estimate the model parameters. The expressions for model parameters were obtained by mathematical approximation methods using analytic horizontal and vertical components of the Hilbert Transform. In the application to the real data, to obtain better gradients in the Hilbert Transform the noise in the anomalies was filtered out. Then the model parameters were calculated by the gradients of the filtered anomalies. These two methods applied to one dimensional Gravity data and the models were obtained. This study shows that the results from each method are in accordance and they should be used together to estimate the model parameters from the potantial field data.

COMBINED GEOPHYSICAL RESEARCH WITHIN NORTH DOBROGEA OROGENE, ROMANIA

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The paper mainly deals with the problem of data representation in order to properly point out the connections between different geophysical information. Detailed geophysical research (magnetics and gravity) have been carried out within northern North Dobrogea Orogene, near the Ukrainian state border, allowing the achievement of some 2 D and 3 D tentative interpretative models. To offer a depth control to the potential field based structural models, three refraction seismics lines were added. By using various potential field transformations interesting correlation between gravity, magnetics and seismics data were revealed. Thus, while the Bouguer and geomagnetic anomaly maps do not evidenced obvious correlation, the vertical gradient of gravity data offered a rather similar pattern to the geomagnetic anomaly. On the other hand, basic igneous rocks within the basement, pointed out by geomagnetic highs and weak gravity maxims, were reflected in local increasing of the elastic waves velocities.

ON THE SOLUTION OF THE INVERSE PROBLEMS OF POTENTIAL FIELDS WITH AN OPTIMAL ORTOGONAL PRISM

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The possibility of solution of the inverse problems of potential fields with an optimal rectangular prism is investigated here. A suitable computer program is worked out and a number of experiments are made with it. The unknown parameters of the model (the location, dementions and the density of the optimal prism) are determined through optimization. The method of Rosenbrock is used for this purpose. Thew program can work with fixed and unknown density. In both cases reasonable results are opbtained. The inverse magnetic problem can be solved in a similar way, both with fixed and unknown direction of the magnetization.

INTRODUCING LONG WAVELENTHES IN GLOBAL MAGNETIZATION MODELS TO DELINEATE AGE PROVINCES

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It has been shown that a global magnetization contrast does exist between continental and oceanic lithospheres. Such a contrast generates magnetic anomalies whose wavelengths are partly hidden by the field of the geodynamo. The comparison of the field generated by such a contrast with observed anomaly field allready allowed to deduce a mean value of the continental total magnetization. In other studies, it has been observed that continental regions of different tectono-thermal ages may bear different values of vertically induced magnetization. In this new model, the a-priori vertically induced magnetizations are set to different values related to the age. The introduction of such a-priori informations allows us, using an inversion process, to delineate age provinces from POGO and Magsat data.

THE SPECTRAL EVALUATION OF THE GRAVITATIONAL POTENTIAL FIELD AND ITS DERIVATIVES: THE SE-ALPS AS AN EXAMPLE.

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The gravitational potential field and its first and second derivatives are studied, applying the spectral analysis. The mass distributions considered refer to regional problems, wherefore the Earth's curvature can be neglected and the Fourier Transform methodology can be applied. After considering synthetic mass distributions, we evaluate the gravitational potential, the gravitational vector, and the gravitational tensor field due to the crustal roots in a section crossing the SE-Alps. The Moho undulations defining the crustal model are obtained from a gravity 3D inversion applied to the area of the SE-Alps.

GODDARD VENUS GRAVITY MODEL DEVELOPMENT INCLUDING THE APPLICATION OF ALTERNATE SOLUTION CONSTRAINT TECHNIQUES

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The Magellan tracking data, including the post-aerobraking data from mapping cycle 5, and Pioneer Venus Orbiter tracking from 1979-1982 are combined to develop a gravitational field model of Venus complete to degree and order 90. In an effort to improve the stability of the orbit determination and gravity solutions, multiple day solution arcs were used in the processing of the Magellan X and S band ramped Doppler tracking data. The resulting gravity potential model, Love number, and planetary orientation will be evaluated against other efforts. Additionally, the choice of solution constraint method will also be discussed, including the application of eigenvalue analysis to remove poorly determined combinations of gravity parameters.

A SOLUTION OF INVERSE PROBLEM OF POTENTIAL IN THE CLASS OF STAR BODIES

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The inverse problems of gravimetry and magnitometry for complex fields sources often are solved by selection method. This method demands to know the initial model. The interpretation problem is being solved inside choosing class of models. The class of star bodies is chosen. In this class inverse problem have unique and stable solution. In star’s centres are fixed inside this body and we to describe external surface in spherical co-ordinates. This function unimodal, patial derivatives are restricted a finite number. A small set of parameters allow to describe complex anomalous object. The solution of direct and inverse problem for this task is carried. The anomalous gravimetric and magnetometric fields are calculated in external points. The form of source is restored in calculation process. Model examples are considered.

A RAPID METHOD ON THREE-DIMENSIONAL ELECTRICAL RESISTIVITY

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Numerical modeling is an important part of tomographical methods. Generally, methods based on finite differences or on finite elements are used. Due to the fact, that this forward modeling is very time-consuming, it does not allow tomographical treatment of larger quantities of electrical measurements with sufficient resolution. To avoid this problem, a simple and rapid method for the forward modeling of electrical resistivity measurements with any electrode system was developed. The apparent specific resistivities thereby are calculated from the conductivity distribution in the subsurface using sensitivities. To determine the sensitivity of a measuring configuration with respect to a conductivity alteration the reciprocity principle of Geselowitz was applied. In contrast to classic methods (finite differences, finite elements) this method is distinguished by high computing speed. Practicabilities and limits of this method are shown at numerical models and measurements. In particular, we investigate errors in the tomographical inversion caused by high resistivity contrasts.

HOW LARGE IS THE NON-HYDROSTATIC PART OF THE GEOPOTENTIAL COEFFICIENT C_{20}?

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Since the early sixties, it has been commonly believed that the observed fully normalized geopotential coefficient $C_{20} = -J_2/\sqrt{5} \approx -484.2 \times 10^{-6}$ of degree 2 and order 0 contains a non-hydrostatic part $C_{20}^{nh} = C_{20} - C_{20}^{h}$ amounting to about -4.5×10^{-6}. In absolute value, this non-hydrostatic contribution is more than twice larger than the second largest coefficient $C_{31} \approx +2.0 \times 10^{-6}$, and almost five times larger than the third largest coefficient $C_{30} \approx +9.6 \times 10^{-7}$. All other coefficients $|C_{nm}|$, $|S_{nm}|$ are at least one order of magnitude smaller than $|C_{20}^{nh}|$. It thus appears that the Earth's shape seems to have a very significant anomaly of degree 2 and order 0. The latter is usually ascribed to a particular convection pattern in the mantle. However, we should realize that, owing to the fact that the Earth is *not* in hydrostatic balance, we have no practical means to know its exact hydrostatic equilibrium shape. Consequently, we have no means to evaluate accurately C_{20}^{nh}, contrarily to the customary claim that this shape can be derived from the seismologically derived density distribution. We discuss in detail why the actual value of $|C_{20}^{nh}|$ is presumably much smaller than the value used hitherto for the modelling of mantle convection.

A METHOD TO DETERMINE THE EXCESS MASS AND THE MAGNETIC MOMENT FROM POTENTIAL FIELD ANOMALIES

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Potential field theory shows that the total mass excess of a source may be computed from its gravity anomaly. The average density or the volume of the source may be derived from it. The classical integration formula suffers however of some intrinsic limitations. The first of them is that it needs a perfect zero-level evaluation. The second is that the presence of interference effects, of either low or high wavelength, leads to wrong results. We suggest an inverse method that assumes the multipole expansion of the field as the forward problem, the parameters to be determined being the moments. After inversion of a data-vector along the vertical direction, the mass excess is computed by the monopolar term coefficient. The advantage of the method is that it may be applied on selected vertical profiles, i. e. far from local interfering anomalies. We discuss also its stability in the presence of low-wavelengths interferences.
Another advantage is that the same approach may be also used for the derivatives of the gravity field and for the magnetic field.
The method is applied to real data.

THE MODERN STATE OF THE STUDY OF THE GRAVITY NON-TIDAL CHANGES

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The problem of the gravity non-tidal changes is appeared in 70-ty years, (XVI General Assambly MGGS, Grenoble, 1975), due to the gradual rise of the measurements precission (now absolute and relative measurements are carried out with some unit of mgl precission). The possibility of more effective study of the gravity non-tidal changes of global, regional and local character is appeared.
Significance of this problem is international. Therefore by the efforts of many world scientists the global gravity nefwork of high accuracy is created. As a result of this works the correlation conection between unregular gravity changes and the angle velocity of Earth's rotation, recent vertical crustal movements, Earth's poles movements is discovered.
Author of this article is mounted that the non-tidal gravity variations the atmospheric processes (the variations of the air masses and the snow coverage) hydrological regime of the underground waters, seismo-tectonic processes, volcanism, masses redistribution at extraction of the oil and gass etc.may be the causes.

LOCALIZED WAVELET DENOISING OF POTENTIAL FIELD DATA

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Gravity and magnetic fields of the Crust are a blend of effects of different scales which are related to sources buried at different depths. But noise of either geological, instrumental or numerical nature is in turn added to the above signals. Moreover, typical functional transformations of potential field, such as vertical derivative of gravity, greatly enhance the noisy part of the signal and determine an unfavourable signal-to-noise ratio.
Classical noise-reducing techniques assume an high-frequency content for the noise and allow denoising by application of low-frequency filters. But this operation has the main disadvantage of acting uniformely on a global scale, since it is uses a Fourier basis. We propose to use instead a local technique based on a wavelet basis. Two different wavelet transformations were used, the former related to the best orthogonal wavelet basis and the latter to the shiftable and steerable wavelet basis, as defined by Simoncelli et al. We compare the global "Fourier" denoising with the local denoising obtained by both the transforms for the vertical derivative of the gravity field of Sicily (Italy). The results show that a local wavelet denoising is a powerful tool to obtain a high resolution information from gravity data.

DEPOCENTERS IN NORTH EGYPT APPROVED FROM POTENTIAL FIELD DATA

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The Northern Egypt, as a part of North Africa, has been subjected to distinct tectonic regimes since the Palaeozoic time, these have resulted in the construction of many sub-basins, ridges, troughs and platforms. At this task, potential field (Bouguer gravity and total magnetic intensity) maps guided by well data, are conceived in an integrative modelling operation to institute the structural footprints ensuing from variant tectonic regimes and their issue on hydrocarbon accumulations.
Introductory, horizontal vector maps are constructed to delineate the general faulting and folding structures.Then, wave filtering, using low-cut, high-cut and band-pass types, is carried out to differentiate the shallow, intermediate and deep-seated effects. Besides, Fourier and Hilbert transformations are conducted through profiles to detail specifically the depths of the causative features. Finally, all the previous results integrated with the subsurface geologic information are utilized in computation of density models covering almost the study area. These models reveal the structural features that control the interesting litho-stratigraphic units of the considered sequence.
Seven sub-basin can be recognized: Shusham, Dahab, Natrun, Abu Gharadig, Matruh, Siwa and Gundi. The first four sub-basins are proved to be oil provinces but the other are not explored yet. Most of the existing oilfields in the area are located at the intersections between NW- to WNW- and NE- to ENE-trending fault systems.

RESULTS OF GEOPHYSICAL AND GEOLOGICAL STUDY OF THE KRAKA OPHIOLITE MASSIFFS ON THE SOUTH URALS

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Kraka massiffs consist of less depleted hyperbasites of the Urals. Massifs and surrounding continent-slope and volcanic complexes as a whole are not typical for Western paleocontinental sector of the Urals. We constructed the geological strip-map and crossection. Petrological and geochemical researches of hyperbasites were conducted, and also stratigraphy and tectonic of surrounding complexes were studied. The interpretations of gravity and magnetic fields were carried out and alternative variants of cross-sections were constructed. Results showed that massifs have the flat positions. The greatest depth of the hyperbasite complex were calculated under the Middle Kraka - 4 km. However, if the density of rock for deeper part of the block is more than at the surface, then the thickness of bodies is about 2 km. Both variants are not contradict to the idea that the Kraka are the allochtons.

THE STRUCTURE AND THERMAL STATE OF ACTIVE VOLCANIC CENTRES IN ICELAND STUDIED WITH GRAVITY AND MAGNETICS

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Gravity data have been used to study the internal structure of some of the active volcanic centres in Iceland, including the subglacial volcanoes of Grímsvötn, Bárðarbunga and Mýrdalsjökull. Bouguer gravity highs of 20-40 mGals are associated with these volcanoes. Most volcanic centres in the rift zone have developed calderas; those that have been studied with modelling, show a similar overall structure: A large dense intrusive mass is present in the uppermost 5-8 km of the crust; smaller high density masses often occupy the uppermost 2 km under the caldera margins. For the centres studied, the gravity data suggest that the upper crust under the volcanoes is predominantly solid; small bodies (~10 km^3) with densities consistent with basaltic magma can be accommodated but are usually not required to satisfy the data. Modelling of the magnetization suggests that for the Grímsvötn volcano, the large upper crustal intrusion is nonmagnetic. It is inferred that it may be hot, above the Curie point, and probably an important source of heat for the very powerful Grímsvötn geothermal area. A similar situation may be occur at some other Icelandic volcanoes. The results obtained show that the combined interpretation of gravity and magnetic data is a useful tool in studying the thermal state of Icelandic central volcanoes.

DELINEATION OF SEDIMENTARY BASINS AND CRUSTAL THICKNESS IN EL MINIA - ASSIUT AREA, EGYPT BY USING 3-D GRAVITY AND 2.5-D MAGNETIC MODELLING

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The use of combined gravity and magnetic modelling has become increasingly important in recent years due to the necessity of constructing more realistic models of geological structures such as sedimentary basins. Within the area of interest, twenty magnetic profiles, reduced to pole, were modelled using a 2-D modelling algorithm to determine the shape and depth of the magnetic source body. In addition to this gravity anomalies over the study area were modelled using a 3-D interactive gravity modelling program to determine the thickness of the sedimentary section as well as of the appropriate crust. The models are constrained by well data, regional geology and refraction seismic investigations which were surveyed in the southern parts of the Gulf of Suez, east of the study area. Well-data, regional geology as well as magnetic susceptibility of different rock types were used as a constrain. For both data sets, the Fast Fourier Transform technique were used to produce a group of low, band and high pass filtered maps at different wave length. The main objective of filtering was to separate and enhance the anomaly of different sources. The parameters of the sources influencing the anomaly, especially the depth, are derived from the amplitude spectrum.
There is good accordance between the forward modelled gravity map using the results of the 3-D inversion and the measured data set. The depth of the basement in the study area changes between 1 and 5 km. Supported by the seismic results, the depth of the Moho in the study area reaches to about 30 km and the continental crust is thinning out towards the Red Sea.

AN EFFECTIVE MASS DISTRIBUTION AMONG SOURCES OF THE EXTERNAL GRAVITY FIELD

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The principal objective of this paper is to find an effective mass distribution among all sources of the gravity potential of the Earth. Let B be a set of all positive mass distributions inside Ω (the body of the Earth) such that on a given set of surface points (profile) their potentials reproduce the gravity potential of the Earth and have a common center of gravity. The crucial question is: Does there exists a mass distribution $\mu_0 \in B$ such that it is concentrated as much as possible around the Earth's center of gravity, i.e., such that it has a "smallest" support? (Note that $\operatorname{supp} \mu_0 \equiv \overline{\{x \in \Omega : \mu_0(x) \neq 0\}}$, where the bar denotes the closer in 3-dimensional Euclidean space.) A similar question is also posed for a set of all positive mass distributions inside Ω that reproduce a given sample of Stokes' parameters of the Earth. Problems like these were not solved completely so far. Nevertheless we believe that there is a way how to find the distribution μ_0, though by means of a sequence of approximation steps and we demonstrate it in numerical examples. In our reasoning we also use the famous méthod de balayage.

Deriving gravity field parameters from terrestrial gravity measurements

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Relative gravity measurements are hampered with the well known problem of unpredictable instrument drift. Usually one attempts to solve this by establishing the drift and the individual point values from the field readings and then to continue with the analysis of the thus derived „observations" with some geodetic, geophysical or geological aim in mind. In contrast, we attempt to use the field readings directly to define the drift characteristics, gravity point values and effects looked for. Especially, we wish to extract small space-time variations of gravity in two regions in Iceland: a region of current glacial isostatic adjustment near the ice cap Vatnajökull, and the Krafla volcanic complex. We use an inversion scheme with a parametrization for the suspected, but unknown effects. The whole set of field observations over several years is included in the analysis which is extended to Icelandic base stations and field points that have been repeatedly observed and for which gravity values have been derived in the past. Thus the data set includes our own raw data and data published in different degrees of analysis by Icelandic and German institutions. Several different instruments (including absolute gravity meters) have been used. The discrepancies between point values for different times are interpreted by a set of parameters including individual reading errors, scale factors, and temporal variations with a smooth space-time behavior. There is no unique solution, but variations of assumptions within plausible limits allows us to present results with reasonable confidence limits. The interpretation of the temporal gravity variations is compared to model predictions.

GRAVITY AND GEODYNAMIC INVESTIGATIONS OF THE HARZ MOUNTAINS/GERMANY FROM 1991 TO 1997

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Since 1990 the Harz Mountains can be again investigated as one complex. A new Bouguer anomaly map is presented and the various gravity anomalies are discussed and interpretations are carried out by high-resolution 3-D gravity modelings. Main subjects of interest in the studies are the northern boundary fault zone of the Harz Mountains (HNBF), the Brocken and Ramberg Granites, the source of the prominent Benneckenstein Gravity High and the surrounding basins. The results of the gravity modelings show e.g.: Mean values of dip and vertical displacement of the HNBF are 3400 m and 70°, respectively. The two granites are distinctly different. The Brocken Granite is shallow, whereas the Ramberg Granite has a maximum depth of 8.5 km. Investigations on the geodynamic evolution of the Harz Mountains are carried out using the finite-element method (FEM). On the basis of the results of gravity modelings, 3-D FE-models are developed. Different assumptions regarding the evolution of the Harz Mountains, the isostatic process, strike-slip tectonics and intrusions are discussed. The results of the FE-modelings do not contradict geological ideas.

INFLUENCES OF THE VARIATIONS IN THE SHAPE, SIZE, AND MASS DISTRIBUTION ON THE GLOBAL AND LOCAL GRAVITY FIELD OF THE EARTH

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The time dependency of the gravity field outside of the Earth have long been observed. Variations in the shape, size and interior mass distribution are important factors that may affect the gravity field both in global and local scales. In this paper, the variation of the gravity potential value on the geoid that caused by the variations in the shape and size of the Earth are estimated. The effects of the variation in mass distribution on the local geoid and gravity anomalies in the case of Fennoscandia are studied by assuming a mass flow model of spherical cap that possibly taken place in company with the land uplift phenomenon.

The Earth crust structure in the continent-ocean transition zone according to potential field data interpretation in Arctic

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The interpretation is based on the gravity and magnetic maps which were issued after amalgamation of data of many surveys. Modern methods of data analysis together with seismic data have allowed a recently revised geologic picture of Russian Arctic Sea shelves based on gravity and magnetic data. Amplitude and frequency of gravity and magnetic anomalies were initially investigated using double Fourier spectrum analysis. This was followed by application of transformations, filtering, and "moving windows" analysis. Then an analysis of sources and the nature of the anomalies via solution of direct and inverse problems was executed. For investigation of gravity sources, grid-approximation base is used because it allows computation of densities in the prespecified limits at the fixed geometry of the cross-section. These limits are set with the help of existing petrophysical data. Density models of transections from Barents Sea to Lomonosov Ridge and from New Siberian Sea to North pole vicinity have been computed as.5D solution, i.e. an extent of bodies along y-axis, perpendicular to the image plane, was taken into account. Calculations of magnetic source depths were executed by different methods of deconvolutions.

UPDATING VALUES FOR THE $C_{21}(IERS)$ AND $S_{21}(IERS)$ GRAVITY COEFFICIENTS

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The current models of the Earth's gravity field are being developed in the IERS (International Earth Rotation Service) Terrestrial Reference Frame. In this frame the gravity coefficients of the second degree and first order distinct from zero, but they are poorly determined in usual way from the Earth's satellites tracking data. Instead, the Earth's C_{21} and S_{21} gravity coefficients are calculated by using observed values of the IERS polar motion parameters. Here we propose to use more complete formulae for calculation of these gravity coefficients than those are presently employed by the most recent models of the geopotential (e.g., the JGM-3 and/or EGM96). The introduced modification actually changes the values of the Earth's C_{21} and S_{21} gravity coefficients being provided by the current IERS Conventions (1996) and included to many models of the geopotential. The updated mean values of the coefficients (normalized) at the epoch of 1986.0 are as follows

$$\bar{C}_{21}(IERS) = -0.190 \times 10^{-9}, \qquad \bar{S}_{21}(IERS) = 1.192 \times 10^{-9}.$$

These values for $\bar{C}_{21}$ and $\bar{S}_{21}$ are proposed for future solutions for the Earth's gravity field and for the new IERS Conventions (1999).

POTENTIAL FIELDS - IMPORTANT INDICATORS OF GEODYNAMIC SETTING OF ANCIENT STRUCTURES OF EARTH'S CRUST?

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Within Baltic Shield and ancient Russian plate shows of ancient tectonic processes were quite intense. An analysis of the structure of the region support the conclusion about of action plate tectonic mechanism in the Late Archean. The most important events of geological evolution has been placed in the periods 3800-2600, 2600-2000, 2000-1650, 1450-1000, 370-290 Ma. The paleotectonic structures have been recorded on basis of position in the over-all structures of the region, time of shows, geodynamic regimes, structural-morphological features of the Earth's crust. All these geodynamic setting are illustrated by character of potential fields.

In the course of studies it was ascertained that features of potential fields are one of the important indicators, which enable to rather confidently distinguish and typify geodynamic structures, even if they are characterized by an «embrionic» evolution. The authors concluded, that in geophysical fields is reflected two tendencies of development of tectonic structures: complication of a structures of the upper horizons of Earth's crust; disappearance of depth characteristics. In this case the potential fields needs to be considered as historical categories. The features of regional and local relations of gravity, magnetic, seismic and geological fields are one of most important indicators of ancient geodynamic settings.

ABOUT GOLD SECTION ON GEOPHYSICAL DATA

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Gold section (GS) proportion is followed in Nature as the " general " beginning and any dynamic systems (and not only of organic origin) work the most effectively then, when their structural organization or regime of functioning are stipulated by law GS. We was make with the purpose of revealing of general laws the sta- tistical analysis of gravitational anomaly field for several planets and their satellites: Earth, Venus, Mars, Moon and Fobos. The parameter V, was resolved at comparison of properties planets and their satelli- tes to use which presents the relation of correlation radius of gravi- tational anomaly fields and radius studied of celestial body. Has appeared, that:all planets with accuracy about 4 meter V the same, as follows 0,351. The relation of V parameter, describing the Moon, there to pa- rameter for Earth gives the size 0,627, that with accuracy about 1,5 coincides with similar ratio for gold section (0,618). And circumstance, that the ratio of V parameters for the Moon and the Earth correspond to the gold section, reflects the general harmony of world, about which is mentioned in many work a.L.Chizhevsky.

A synthesis of the geology and geophysics of the Northern Norrbotten ore province, Sweden

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Better understanding of ore genesis and refined and more efficient prospecting and mining methods developed during the last two decades, have made it possible to reconsider classical ore provinces thought to have stagnating mineral resources. One of these is the Northern Norrbotten ore province in Sweden, where deposits of apatite iron ore, stratiform copper ore, and epigenetic copper-gold ore are the prerequisits for the regional economic policy. Most of the deposits are hosted by Paleoproterozoic greenstones and porphyries (≥ 2.2Ga - 1.88Ga) which are underlain by clastic metasedimentary rocks and Archean basement (≥2.8 Ga - 2.5 Ga). The Geological Survey of Sweden has initiated a project with the objective of reviewing and updating the known Precambrian geology of this area in order to facilitate, e.g., new studies or activities aiming at the extraction of geological resources of economic interest. The results will be presented as synthesis maps at a scale of 1:250000. Principal emphasis will be laid on: 1) the main lithological units, 2) the structural and metamorphic outlines with results from the geophysical interpretation, and 3) the economic geology, i.e. locations of metallic and non-metallic mineral deposits, and alteration zones. Geophysical data are presented as maps showing anomalies of the magnetic total field, Bouguer anomalies, gamma radiation measurements recalculated to contents of K, U, and Th, and electromagnetic data (VLF). All maps as well as geological and geophysical information bound to databases (mineral deposits, geochemical analyses, petrophysics) will be available in digital format on CD-ROM. The project is planned for completion by the end of 1999.

GRAVITY AND GEOID DATA FOR THE VALIDATION OF A 3-D STRUCTURAL MODEL OF EUROPEAN REGION

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Recently a regionalized 3-D structural model of Europe has been compiled (Du Z.J. et al.,1997). The model covers European area from -25 degree E to 35W and from 0 degree N to 70N. The data set has been validated by means of a 3-D gravity model using a 3-D interactive modeling (Goetze and Lahmeyer,1988). Because of the limits of the 3-D gravity program the investigation has been performed using windows having dimensions compatible with the complexity of the structural model.The modelled gravity field has been directly compared with the Bouguer anomaly where possible or reduced to geoid undulations and then compared with the geoid model OSU91. Results of this validation procedure for the Scandinavian region and for the South Europe will be presented.

THE ROLE OF MAGNETIC VECTOR POTENTIAL IN 2-D ELECTROMAGNETIC INDUCTION IN A SPHERICAL EARTH

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We formulate the 2-D forward problem for electromagnetic induction in a spherical earth in a weak sense and solve it by a spectral-finite-element approach. The boundary data used in this formulation consist of the horizontal components of the total magnetic intensity measured on the Earth's surface. In this the weak formulation differs from other methods, which usually use spherical harmonic coefficients of the external sources as input data. The well-known Gauss analysis and decomposition of the observed surface magnetic induction into external and internal parts is not necessary to carry out when the weak formulation of the problem is employed.

From two main existing families of formulation, those based on the electric and magnetic inductions and those based on the electrical scalar and magnetic vector potentials, we choose the latter one. The major advantage of solving the electromagnetic induction in azimuthally symmetric earth with purely zonal source is that the vector potential reduces to a scalar quantity; the induced eddy currents are uni-directional.

NUMERICAL DETERMINATION OF FIELD LINES IN GRAVITATIONAL SPACE

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The physical nature of geometrical conditions of the geodetic measurements and of the coordinate systems used in geodesy require an exact knowledge of the Earth's gravity field. Geometrical terms like vertical and horizontal directions etc. depend exclusively on the gravity field, therefore vertical projection of a point located on the surface of the Earth cannot be properly treated if physical circumstances are neglected. Based on a reliable 3-D regional density model of the lithosphere of the Pannonian Basin (Hungary) an effort was made to reconstruct field lines (plumblines) going through topographical masses using the usual numerical approaches applied in the solution of first order ordinary differential equations (Euler's method and higher order approximations which are based on the Richardson extrapolation implemented by the Bulirsh-Stoer method as well as on the solution of the Frenet-equation of a space curve). The deviations (offsets) between horizontal coordinates obtained by geometrical projection along the normals and the physical projection along the plumblines were investigated in "flat Earth" approximation. The results show that even in the situation of a moderate topography (H_{max} = 1015 m) and a regionally balanced geological/tectonic structure the differences may reach several centimeter whereas in the geological surroundings of the Basin (Alpine-Carpathian orogenic belt) those may reach easily the decimeter level resulting in e.g. 20 cm contraction of a baseline of 50-60 km. The absolute values of the deviations are correlated mainly by the topography of the investigated area.

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STUDY OF ULTRAMFIC BELTS IN INNER DINARIDES AND VARDAR ZONE

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Ultaramafic belts of the Jurassic ocean in the Alpine-Mediterranean region have distinctive lateral tectonic position. Their roots or depth distribution are not so clear. We use geomagnetic, gravity and geological data (maps and profiles) to study depth distribution of ultramafic bodies along the ophiolite belts in the area of SE Europe. As potential fields are not with appropriate resolution for valuable interpretation we incorporated other geophysical (MT and DC sounding) as well as geological data in search for model building. We apply this procedure in area of inner Dinarides and the Vardar zone. Deep MT sounding as well as seismology data have been used for comparison of the astenosphere LVL with tectonical settings of ultaramafic bodies. It seems that the astenosphere below Mesozoic passive margin (Dinarides) has now different characteristics then below Mesozoic active margin (Vardar zone). There is some evidence that, at least part of Vardar zone, was the marginal basin during Mesozoic.

MANTLE VISCOSITY, GLACIAL ISOSTASY AND THE ANOMALOUS GRAVITY FIELD

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Interpretation of the free air gravity anomalies over previously glaciated regions continues to be controversial, in no case more so than in connection with the 70 mgal anomaly that currently exists over the Hudson Bay region of Canada. Although the approximate form of the theory first employed by Wu and Peltier (1983) to calculate the expected magnitude of the anomaly was later corrected in Mitrovica and Peltier (1989), both analyses led their authors to the incorrect conclusion that the entire anomaly could be explained in term of incomplete glacial isostatic adjustment. This issue was further explored by Peltier et al. (1992) who employed the realistic ICE-3G model of deglaciation of Tushingham and Peltier (1991), to show that the present day free air gravity anomaly predicted by the corrected theory was far too small to explain the 28 mgal negative anomaly that exists in the range of spherical harmonic degree $0 \leq \ell \leq 8$. Rather, the anomaly was shown to be almost entirely explicable as being due to the influence of the mantle convection process as earlier hypothesized by Cathles (1975). A recent paper by Simons and Hager (1997) has suggested that 50% of the anomaly was due to the GIA process and 50% to convection. We will demonstrate that this "least controversy" solution requires the assumption of a viscosity model that is unacceptable from the perspective of relative sea level and other data related to the GIA process.

CHANGES OF GRAVITY IN RELATION TO OTHER GEODYNAMIC PHENOMENA IN WESTERN BOHEMIA

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In the West Bohemia seismoactive region a relatively intesive earthquake swarm was registered in 1985/1986. The area is located on the crossing of two major geological structures of the intraplate Ohře "rift" and the Cheb-Domažlice graben. A seismological network was established to record the activity. In the 1990s more complex investigations have started, comprising simultaneous GPS and gravity repeated measurements twice a year, precise levelling in selected areas and continuous monitoring of the groundwater level. The gravity measurements were concentrated on a principal profile crossing two major faults and a sedimentary basin in between, and on two related closures covering the main epicentral area. The temporal non-tidal variations of gravity proved certain correlation with seismic activity and groundwater level, respectively. As there were no significant vertical displacements, the changes may be related to geodynamic phenomena like stress accumulation and release, mass redistribution etc. For successful correlation analysis and its statistical confidence a long-term continuation of this four-year investigation must be ensured.

ON THE INVESTIGATIONS OF THE EARTH'S MAGNETIC FIELD

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In the analysis of the magnetic field with current loops the series of investigation is extended - old (1932-1960) and new - (1905-1923 , 1970- 1975) with the purpose - studing the variations of the Magnetic field. The optimization in the investigation of the dreif of the continents with current loops is improved - tree methods (Marquardt, Gradient and the steapest descent) are now used in stead of one. The programe used autometicaly choose the most suitable one for the corresponding situation. This improves not only the solution but olso the precision of the solution. The main results is that in the case with 26 observational points on the whole Earth we now recieve the corresponding solution more quikly than obtained before - with only one optimizational method (the method of Marquard).

AN INTERACTIVE 2D AND 3D GRAVITY MODELLING PROGRAM FOR PERSONAL COMPUTERS.

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A complete PC-based system for the gravity modelling of geological structures has been developed. The system allows for good geometrical simulations of structures, because its ability to interact with external processes (the topographic surface, contact with other bodies and faults that cut and displace two parts of a body) permits the generation of geological models with a great deal of realism. The geometrical parameters that define the model are easily modified; indeed most of them are adjusted automatically.

The system can construct a 3D model directly from the generation of volumes or from the spatial union of bidimensional sections. This last method can be considered a suitable intermediate process between 2D and 3D modelling.

POTENTIAL FIELD DATA INVERSION FOR THREE-DIMENSIONAL OBJECTS OF ARBITRARY SHAPE

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Developed are theoretical foundations, numerical algorithms and computer programs to find a geometry of 3D restricted body, one or several 3D contact surfaces. It should be emphasized, that we have managed to avoid any modelling: new integral equations of the first kind have been derived to find a function determining a geometry of the object sought. The method of local corrections has been suggested, which makes it possible to curtail the time required to solve an inverse problem approximately by an order of magnitude. Our technique has been successfully used in global, prospecting and mining geophysics. Joint inversion of gravity and magnetic data for core mantle boundary relief led us to some hypothesis on the core material flow. 3D relief of the upper boundary of pre-jurassic rocks was found using square gravity data mainly. Subsequent comparison of the relief obtained with the position of the boundary according to the seismic profile, unknown for the author beforehand, has revealed their quite satisfactory coincidence.The volume model of Kendykty granitoid massif has been constructed. 3D geometry of the diorite core in the granite block has been recovered, which lower boundary was expected to be a metallotect. The algorithm has been derived for permanent control over mining process using underground microgravity data. Temporal measurements of gravitational field in the first moment when a block is filled with an ore and in some further moment provide an opportunity to find density contrast surface (barren rock - ore or air - ore boundary).

GEOPHYSICAL INVESTIGATIONS INTO THE DEEP STRUCTURE OF MAMOURA AREA, OFFSHORE LIBYA.

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The Mamoura gravity and magnetic anomalies are located in the Pelagian block of Offshore Libya. Which is part of a continental buffer zone between the African and European plates. Analysis of the power spectra of the anomalies indicates that they result from two sets of sources: a shallow source at a maximum depth of 5 km and a deeper source at a depth of about 8 km. The latter is interpreted as the depth of the local basement, While the former probably refer to the depth of the top of the causative body of the anomalies. These depths are in excellent agreement with those derived from seismic reflection data. The poor correlation between the pseudogravity fields for induced magnetisation with the observed gravity fields strongly suggests that the causative body have remanent magnetizations. The orientations of the total magnetization have been estimated. Three-dimensional interpretations of the magnetic and gravity anomalies suggest causative structures of similar shape. The analysis and interpretation of all the geophysical data combined with the tectonic history of the area suggest that the source of large gravity and magnetic anomalies are related to a Mesozoic extensional phase. The north-south trend of the magnetic anomaly is probably related to the Pre-Cambrian Pan-African deformation, whose trend was reactivated during the Mesozoic extension.

GRAVITY PATTERNS AND CARBONIFEROUS BASE-METAL ORE DEPOSITS IN IRELAND

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Central Ireland contains an extensive carbonate succession of Courceyan to Brigantian age, deposited in fault-bounded sub-basins across the Irish Midlands. Carbonate sediments host base-metal Pb/Zn deposits of pre-Arundian age, with mineralisation episodes controlled by syn-rift crustal extension. As the region is highly glaciated, geological structure is not well mapped. Here we show that the deposits are spatially correlated with a network of 'Caledonian' NE-SW trending and interconnecting weaker NNE-SSW and subtle NW-SE trending gravity lineaments. Gravity derivative maps are used to demonstrate these relationships and it is shown that the occurrence of the ore deposits is related to the local magnitude of the derivatives. This suggests Caledonian basement involvement in the formation of Carboniferous sub-basins and the genesis of base-metal deposits. The continuity of lineaments across the Carboniferous regions into older Palaeozoic terranes, where they usually correlate with mapped faults, indicates strong Caledonian basement control on Variscan tectonic development and related episodes of ore mineralization. The re-activation of older basement fractures seems to have controlled the migration pathways of mineralising fluids and thus possibly the spatial distribution of ore deposits. These methods applied to densely spaced gravity data are a useful tool in understanding basement and basin-fill properties which influence ore genesis.

ON INTEGRAL OPERATORS OF POTENTIAL THEORY AND ITS APPLICATIONS

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The integral operators of Potential Theory are of fundamental interest in various fields of physics and earth sciences. E.g, the double-layer potential and the electrostatic integral operator occur in the integral equation formulation of boundary value problems for the Laplace equation in $\mathbf{R}^3$ whereas the magnetostatic operator plays the same role in the theory of harmonic vector fields. The spectral behaviour, i.e., the behaviour of eigenvalues and eigenfunctions, is a key-property of these operators. For the case that the underlying surface is either a sphere, a spheroid, or, a triaxial ellipsoid explicit expressions for both eigenvalues and eigenfunctions are well-known.
We discuss two applications: First, we consider a model for permanent magnetization of a compact body $D \subset \mathbf{R}^3$. The permanent magnetization is modelled by spatial dipole distributions in D wh which are in equilibrium w.r.t. an energy functional. The determination of such dipole distributions can be reformulated as an eigenvalue problem for the electro- and magnetostatic integral operator on the boundary surface S of D. In a second example, we discuss an integral equation approach to the Ellipsoidal Stokes Problem which occurs in geoid height determination. We obtain conditions for the unique solvability of the accompanying integral equations in terms of eigenvalues of the above integral operators.

ON CORE MODES

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With the advent of superconducting gravimeters sensitive to extremely small periodic changes of gravity (typically of the order of magnitude of 1 ngal), core oscillations can possibly be detected. Once observed and identified within a proper classification scheme, core modes could teach us much about density and temperature gradients in the core. Unfortunately, because these physical quantities are not well known yet — in particular, we do not know the local Brunt-Väisälä frequencies nor do we know the density jump at the inner core boundary (ICB) — we cannot assess with any reliability the range of frequencies where we should search for core modes. Moreover, rotation and ellipticity are factors which complicate tremendously the theoretical computation of core modes. We discuss the use of Cowling's approximation and of the subseismic equation and show that the former makes the problem indeed more manageable whereas the latter is not of much use. We study some general mathematical properties of gravity modes in the non-rotating case, and indicate the main reasons why the period of the free core nutation computed in the traditional way is about 460 days whereas the observed period is close to 435 days. Moreover, we discuss briefly the frequency range where we should look for the Slichter triplet.

ABOUT CONNECTION OF MANTLE AND CRUST IN LITHOSPHERE OF THE URALS

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The complex analysis of various geophysical anomalies permits to make new conclusions about the peculiarities the deep structure upper mantle and crust in nothern and southern sectors of the Urals. The sources of isostatic anomaly, air gravity anomaly, geoptencial anomaly, conductive electric anomaly are placed, mainly, in the upper mantle. The upper mantle in the nothern sector has more density. Bouger anomaly, magnetic regional anomalies, disturbance of the crust, the calculation of anomaly masses distribution, fulfilled on the base deep seismic sounding data on account of correlate connection between the seismic wave velocity and thickness of the rocks proves also that the deep structure crust in nothern and southern sectors are different. There are correlate connection between mantle and crust anomalies. The border between sectors is placed in the interval 54-56 degrees N latitude and coincides with the Ufimian nose of Russian Plate. The Ufimian nose determines the redistribution of pressure in oll region. The reason of that phenomenon is the differentiation of mantle substance. The movement of tectonic activity and disturbance zone of the Urals is observed from east to west.

GLOBAL POSTSEISMIC DEFORMATION: EFFECTS ON THE GRAVITY FIELD

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A global scale analysis of the effects induced by an earthquake on the major geophysical observables requires the adoption of spherical geometry. Our aim is to study in a self consistent way the gravitational perturbations associated with lithospheric shear dislocations both in the co- and postseismic regimes. To perform our investigations we develop a spherical stratified earth model characterized by a Maxwell viscoelastic rheology of the mantle. We carry out a detailed analysis of the space and time-evolution of gravity changes associated with a wide selection of seismic sources, addressing the role played by the viscosity profile of the mantle and by the asthenospheric thickness. As a case study, we perform a synthetic simulation of the 1964 Alaska earthquake to discuss the feasibility of an experimental detection of the postseismic gravitational effects, which would be of great importance in understanding the dynamics and viscosity profile of mantle and asthenosphere.

MAGNETIC AND GRAVITY FIELDS STUDY AT REGIONAL MAGNETIC ANOMALY.

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Manchagh regional magnetic anomaly located at the western edge of East-European platform. It has diameter more than 100 kms and intensity of the total field in epicentre close to 1500 nT. The territory of the anomaly was covered by ground vertical component and airborne total field surveys. Besides a number of profiles of special precise aeromagnetic observations at altitudes from 150 m to 5000 m above ground were carried out there. According to seismological data the thickness of sediments at the territory of anomaly varies from 4000 to 10000 m. We interpreted anomalous field with 2-D and 3-D technique taking into account the demagnetisation factor. According to the results of research two variants of models were constructed. 1. Thick body with the upper edge at the depth of 10 kms and lower margin at 40 kms. 2. Thin body with the upper edge at the depth of 10 kms and lower margin at 20 kms. The rather week gravity anomaly was also investigated and joint interpretation of magnetic and gravity field was carried out. Magnetic basement relief and relief of diurnal surface was also taken into consideration.

Regional approximations of the gravity anomaly field in Central and Northern Europe

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Two types of linear analytical approximations of the gravity anomaly field are considered with regard to their usefulness in describing the gravity field for territories up to several millions square kilometers.
The first type is an adaptation of a linear approximation of functions which are harmonic outside a sphere and for the case that the gravity data is given on the physical surface of the Earth. In that case the elaboration of a linear analytical model leads to the problem of finding out approximate solutions of strongly underdetermined systems of linear algebraic equations.
The second type is based on a generalized Backus-Gilbert approach, which stands for a variant of integral representation methods. In the frame of this approach it is required to find an approximate solution of a system of linear equations with symmetric positive semidefinite quadratic matrices.
The composed software to get solutions for both types of approximations is represented. Both approaches were applied to get regional approximations of gravitational field elements for Scandinavia and Germany.
An analysis of the obtained models is presented together with a characteristic of the field of application for each of the methods.

NON-LINEAR GRAVITY INVERSION INCORPORATING BOTH DENSITY AND GEOMETRIC PARAMETERS

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Most gravity inversion schemes try to fit unknown densities in a big number of cells with predefined shape. This inversion problem has the advantage of being linear, at least when a-priori information on the cell-densities is assumed to be well described by a gaussian distribution. Because this is usually not the case, complex (iterative) inversion algorithms must be used to include complex conditions expressing the a-priori knowledge in terms of relations between densties in neighboured or otherwise related cells. For such problems it is easier to express the geometric a-priori information in geometric parameters. Because the a-priori information turns the linear problem into a non-linear one anyhow, the use of the non-linear relations between geometry and gravity observations is no big disadvantage anymore. The non-linearity is in most cases not too severe, so that itaration with the linearzed version of the problem converges usually quit soon. It is also much easier to define general geologic a-priori information in terms of just a few geometric parameters, which allows for a better reduction of the solution space of the non-unique gravimetric inverse problem.

MAPPING GRAVI-EQUIPOTENTIAL SURFACES INSIDE MASSES BY DIRECT USE OF NEWTONS INTEGRAL

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Abstract: The *geoid* is conceptually defined as an equipotential surface in a sense of Newton's law. However, the present day geodetic definition of the *geoid* circumvents the direct use of Newton's integral, i.e. the direct use of mass density of the attracting body. In practise, only very simple mass density models are used. The visible topography and the (sea) water have, respectively, standard mass density values of 2.67 g/cm^3 and 1.03 g/cm^3. Furthermore, the topographical masses are often compensated in depth by some standard isostatic compensation model, e.g. Airy-Heiskanen. The (existing) true mass density in the subsurface can deviate considerably from the above simple mass density model. Assuming that both mass density models (the simple one and the true one) are consistent with the measured surface gravity signal, the difference between the two belongs to the null space of the inverse gravimetric problem (which has other elements than the zero mass density distribution).

Consequently, modelling of the equipotential surfaces inside the masses as it is done in Geodesy deviates from the equipotential surfaces obtained by the direct use of Newton's integral. The purpose of this contribution is to study, quantitatively, how big this effect is. The study area is Jutland peninsula (Denmark). The area (256 km x 206 km) is flat (the hights do not exceed 200 m above mean sea level). However, there are large mass density variations in the subsurface. The depths to various geological units are known to the approximate depth of 10000 m and can be represented on a 2 km x 2 km grid. In an earlier study, a detailed mass density model for different geological units was obtained. The model is based on a combination of borehole information and surface gravity data and includes depth variations of the mass density within geological units. Thus, changes of the gravity potential with depth can be determined directly.

ON INCREMENTAL STRESSES CAUSED BY TIDES, VARIABLE ROTATION RATE OR SURFACE MASS LOADS, AND EARTHQUAKE TRIGGERING

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In a recent paper, Varga and Grafarend [*Phys. Earth Planet. Int.*, 93 (1996), 285–297] consider the distribution of luni-solar elastic tidal stresses within the Earth's mantle, and discuss rather briefly a possible correlation between tidal stress and the occurrence in time of seismic events. Although a tidal triggering of earthquakes can by no means be excluded, their paper hardly provides more direct evidence than had been given previously by other authors. Nevertheless, it occurs to us that it is important to have an exact idea of the tidal stresses within the Earth, as well as of the stresses associated with changes of the Earth's spin or with surface mass loads such as variable ice caps on a long time scale, variable air masses on shorter time scales. Varga and Grafarend provide such stress curves for zonal, tesseral and sectorial tides, but their results are marred by the fact that they use the equations for static deformation and thus are led to impose the unrealistic physical constraint that the core-mantle boundary be stress-free. Here we study the effect of this questionable assumption by computing the incremental stress distributions within crust, mantle, and core using the correct dynamic approach.

TEMPORAL VARIATION OF SECOND DEGREE GEOPOTENTIAL

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The temporal variation of the external gravity potential can be described with the time derivative of the second zonal geopotential coefficient J_2. The dJ_2/dt value derived from Lageos and Starlette data under the condition of conserved angular momentum apparently contradict to results obtained for the secular changes in J_2 derived from the variation in axial rotation speed in geological time-scale. Studies of the present glacial discharges show that the dJ_2/dt values deduced from laser data of Lageos and Starlette can be explained by this phenomenon. On the other hand the secular decrease of the angular speed in geological scale of time can be completely explained by tidal effects. This conclusion is based on the study of the angular momentum equation and on dJ_2/dt value derived from paleontological spindown values.

THEORY OF POST-SEISMIC DEFORMATION AND GRAVITY POTENTIAL FIELD

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An earthquake causes a redistribution of the strain fields in crust, lithosphere and mantle. The relaxation of these strain fields is detectable at the surface of the Earth as expontial-like decaying deformation patterns by GPS-networks. From relating measurements of post-seismic behaviour to the earthquake source parameters by means of viscoelastic Earth models, our knowledge about the Earth's internal constitution, creep properties and dynamics can be significantly enhanced.
An overview is given of the mathematical formalisms by which post-seismic relaxation can be modelled for a spherically stratified, self-gravitating Earth model with a viscoelastic rheology. These formalisms show much resemblance with formalisms for treating post-glacial rebound. Special attention will be devoted to the strong influence that stratification of the shallow layers has on post-seismic deformation and gravity fields.

THE CRUSTAL STRUCTURE AND THE GEOID IN THE FENNOSCANDIAN SHIELD

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According to the theory of isostasy, the Earth is a variable mass body that may deform itself in order to reach an equilibrium stage. The land uplift phenomenon in the Fennoscandian Shield is believed to be such a process that is caused by the loading and unloading of ice sheets in the Ice Ages. The geoid, as an equipotential surface of the Earth's gravity filed, is determined by the mass distribution interior of the Earth. The geoid varies since the variations in mass distribution occurred in company with the land uplift. In this paper, the effects of mass anomalies in the crust on the geoid are estimated in order to get better understandings to the land uplift process. 3D structural model of the crust is constructed according to deep seismic refraction/reflection studies; and empirical relations between the densities and velocities are applied. It have been found that the crust plays an important part in the characteristics of the local geoid.

On applying the regularization WIGCONT to potential field downward continuation - consequences

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The SHA field model for the internal magnetic field enables to apply a regularization procedure for a downward field continuation that is derived from the fact that the physical content of the SHA terms depends on the distance of the reference surface (e.q. sphere) from the field sources.
When this regularization procedure WIGCONT is used, simultaneous field models for different reference spheres e.g. the Earth's surface and the satellite orbit can be compared and evaluated stepwise for the relevant contributions of the SHA terms per degree and order. This precaution also yields constraints for measuring the internal field in the satellite orbit. Moreover, there are also consequences for what kind of time variations of the internal field can be measured there.

THE INTERPRETATION OF GEOID ANOMALIES BY AN AUTOMATED FITTING METHOD

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The algorithm and program for the geoid anomalies interpretation are developed in process of preparation for the first sea trip to a Ukrainian antarctic station. The software is based on the optimization of sum of square differences between a measuring and modeling geoid anomalous components. The 2?D prisms with polygonal section are used for the parametrization of anomalous sources. The effective optimization procedure is applied for the minimization of the objective functions. It includes the gradient-based algorithms and singular values decomposition technique. The developed software allows to conduct automated fitting of geometrical and physical (density and magnetization vector components) parameters of anomalous sources both, by using geoid, gravity and magnetic anomalous data separately and geoid-gravity, geoid-magnetic, gravity-magnetic anomalous data jointly. The linear transformations of the geoid, gravity and magnetic anomalies also can be used in the interpretation process. The developed software will be used for the interpretation of geophysical observation data in the antarctic sea trip. that is planed for the winter 1996.

The new aproach to recounting of potential fields.

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Let us take a look at questions about recounting of potential fields and questions about calculation of the highest derivatives considering new mathematical model. In existing algorithms for initial surface of presenting fields was taken planetree or profile. Here considering problem of recounting of potential fields in different presentation: 1. function U(x,y,z)in external area G1 is unbreakable everywhere considering to surface , including this surface. 2. function U(x,y,z) in G1 area satisfies Laplas equation 3. function U(x,z) takes in given value on surface of limited sizes S1; surface S1 and can have the same point, the point of contact of sphere and surface (3-dimensional problem) and point of contact of circle and line (in a case of 2-dimensional problem). Function U(x,y,z) aspires to 0 when point (x,y,z) aspires to infinity. The main difference of presentation this problem from usual presentation of the same problem is the fact that we have the enclosed area, which includes sources of field with surface , and initial function is presenting on another, non-enclosed area of ultimate sizes S1. For surface, which includes area, which has anomalistic sources, is taken surface of circle, the cut of tall hat with vertical planetree (2-dimensional) or cut of sphere (3-dimensional). The area of presentation of initial field is a part of profile (a,b) which coincide with axis OX.

ONE NEW METHOD FOR TRANSFORMATION OF POTENTIAL FIELDS TOWARDS ELEMENTARY SOURCES

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One new method for transformation of potential fields towards elementary sources is proposed here. A suitable computer program is worked out and a number of theoretical and real experiments are carried out with it. In general, the obtained results (maps of the corresponding transformed field) visualy are very similar to those obtained in the analytical downward continuation of the respective potential field, but this operation (downward continuation) is not always correct. In particular, on the basis of all this, the magnetic field of the territory of Bulgaria is transformed towards optimal magnetic point sources and the corresponding map is prepared. The obtained results confirms the megablock structure of the Earth's crust in Bulgaria, known on the basis of other independent information.

SOME RESULTS ON THE INTERPRETATION OF SEVERAL MAGNETIC ANOMALIES WITH ELEMENTARY SOURCES

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Several complicated magnetic anomalies from the territory of South Bulgaria are interpretate with a set of elementary sources. The unknown parameters of the model (the depths of the sources and the respective masses) are approximately determined through optimization. A model of the corresponding magnetic field in the region is constructed on this basis. The obtained results seems to be with a good agreement with the expectations on the base of other independent information.

SOME RESULTS Of THE ANALYSIS OF THE ZARAGOZA GRAVITY ANOMALY WITH A SET OF POINT SOURCES

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The Zaragoza gravity anomaly was studied with a set of point masses model. After a preliminary polynomial approximation to eliminate the main part of the regional trend (so that to ease the optimization), the local gravity anomalies together with the rest of the trend are modeled with a set of point sources and a linear trend. The unknown parameters of the suggested model are determined through optimization. The obtained results seems to be quite in agreement with the carstic cavities filled with water or sediments supposed to be at depths of 12 to 20 m. and the terrain colapces taken place in the last years in this region (Alcala de Ebro village - Zaragoza, Spain).

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SE37 Regional magnetic surveys: data, models and charts

Convener: Best, A.
Co-Convener: Chiappini, M.

MAGNETIC SURVEY OF THE AREA NORTHWEST OF EL-QUSEIR-EGYPT

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ABSTRACT: Magnetic survey is made for the area between wadi abuhamra and wadi abu shekeelby two proton magnetometers,one for the base station and the other for the survey for the totalforce. the study of the total magnetic Intensity anomaly map of the area reveals that there are 13 Normal faults, 6 grabens,4 horsts,and 2 step faulting systems in the basement complex of the area.

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ABSTRACT: A detailed magnetic Survey of wadi Natrun area was made for the Vertical Component of the geomagnetic field Using Fanselau Torsion magnetometer. The study of the area in terms of its geological strucutre revealed that the are twenty faults trending NW-SE,NE-SW,EW, and N-S.

ON THE NORMAL GEOMAGNETIC FIELD (NGF). MODELING AND UNDERSTANDING

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The paper deals with problems related to ngf concept within confined areas. Both spherical harmonic and polynomial regression based ngf models for the Romanian territory have been performed and compared for various magnetic epochs trying to decode their limits and geological support. The analysis clearly showed that local spherical harmonic ngf models are strongly affected by regional circumstances. The neighborhood of the Kursk geomagnetic anomaly determines a local trend within the equivalent geomagnetic dipole field (n=1, 2) by forcing magnetic contours to step toward north-east instead of north-west as in the case of the global models. Compared to the spherical harmonic models, ngf models constructed as second order polynomials proved to be close to the field of the equivalent geomagnetic eccentric dipole (n=2), except for a residual anomaly central Romania located. Increasing errors through out the state border, due to the neglecting of the Earth's curvature, were also evidenced.

MAGNETIC SURVEY OF RAS GHARIB AREA IN EGYPT FOR PETROLEUM EXPLORATION

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ABSTRACT: A detailed magnetic Survey was made For Ras Gharib area for The vertical Component of the Geomagnetic field using fanselau Torsion magnetoneter. The Study of the area revealed that there are eleven faults trending Nw-SE,NE-Sw,E-W,and N-S.The Petroleum oil May be reached to the surface of the earth through the faults F_1,F_2,F_3,F_4 F_5,F_6,and F_7.

GEOMAGNETIC FIELD ON THE TERRITORY OF YUGOSLAVIA FOR THE EPOCH 1995.5.

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The renewed three-component geomagnetic survey on the territory of Yugoslavia has been realized during two years time period between 1994 and 1996. The intensity of the corresponding components of a geomagnetic field vector were measured at 240 different locations, distributed on the whole area (with average distance of 20 km between neighbouring locations) all values were reduced to the epoch 1995.5, using data from the geomagnetic observatory Grocka. On the basis of this data applying a rectangular harmonic analysis magnetic as well as magnetic anomaly maps were derived for corresponding field component. The analytical representanion of measured field data with help of two-dimensional Fourier series alow as a.) to derive consistent pair of northward (X) and eastward (Y) component magnetic maps; b.) and in a case of anomaly magnetic maps it yields an effective tool for magnetic interpretation.

COORDINATED MAGNETIC REPEAT STATION SURVEY IN EUROPE

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In the last years several institutions have carried out magnetic surveys for the study of the geomagnetic field, especially for the secular variations (SV) and magnetic anomalies. The density of repeat stations and the time interval between the surveys varies from country to country. Furthermore, conducting such surveys depends increasingly on the economic situation of the countries. Therefore it seems to be favourable to increase the scientific content of the survey by coupling the measurements of the repeat stations along the border of neighbouring countries.
During 1997 institutes from Austria, Czech Republic, France, Germany and Poland have undertaken common measurements on both sides of the border of Germany. The aim was to couple the results of recent measurements for a comprehensive magnetic mapping. The paper intend to give a report about the measurements including data processing and evaluation (reduction method), the used magnetic equipment, the comparison between different stations of first order and so on.

Ordinary and spherical cap harmonics and an integral matrix-based approach for modelling regional magnetic data

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In a spherical cap- like region there exists a relation connecting the spherical cap harmonics and the ordinary spherical harmonics, involving the values of the basis functions or their theta-derivatives at the cap boundary. From this finding, an integral matrix-based approach can be introduced and applied for modelling magnetic data taken in a regional cap-like region.

THE STRUCTURE OF THE URALS CRUST ACCORDING TO GEOMAGNETIC DATA

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The Urals orogenic belt is one of the great structural feature of the Eurasian continent. According to recent point of view Uralian crust was developed during the collision of island arc and micro continental fragments with the structures of East European Craton. A great variety of geological and geophysical investigations was carried out at the Southern and Middle Urals during last decade in the framework of Uralides Project as a part of Europrobe international Programme. The range of geomagnetic investigation of the lithosphere was carried out at the Urals during last two decade. One of the most important part of this research complex is precise aeromagnetic survey along the network of profiles with the length up to 1200 kms crossing the orogenic belt in latitudinal direction. Besides the airborne survey we used satellite magnetic data and investigated all spectrum of geomagnetic variations from short-period to secular, studied magnetic field dynamic and used new method for interpretation of experimental data. As a consequence of this research we construct the magnetic model of the crust along number of profiles. As a result of study we come to conclusion that the Urals has practically non-magnetic crust in comparison with the magnetization of the crust of adjacent platforms.

MABNETIC ATLAS OF THE BALTIC SEA

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Results of measurements of the geomagnetic field on the Baltic Sea, using nonmagnetic ship R/V Zarya in the years 1970-1990, have been collected in the digital data base. Magnetic data, with temporal variation corrections included, were reduced to the epoch 1995.5. The whole length of the ship tacks along which the continuous measurements were performed, was more than 30 000 n.m. The average distance between individual tacks was about 2.5 n.m. Accuracy of measurements was of 25-35 nT for F, Z and H and 0.2° -0.3° for D. Using the mentioned above data base, the 1 x 1 km grid has been computed and then the graphical Atlas of Magnetic Maps for Baltic Sea has been worked out. Atlas contains maps of D, I, F, Z, H, Fa, Za, Ha in the scale of 1 : 5 000 000. Maps of D and Fa are also presented in the scale of 1 : 1 500 000. Maps of the normal field and maps of isopores are added to the Atlas as well as the map of the tacks. As an example of using the data base, depths of the sources of magnetic anomalies have been calculated. Several systems of linear disruption of the crystalline foundation being perpendicular to the already known systems have been revealed. These systems correlate with contemporary bottom relief. The CD ROM with magnetic data for 1 x 1 km grid, description of data, method of compilling the maps and method of their interpretation, are enclosed to the Atlas.

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RAPID INTERPRETATION OF MAGNETIC ANOMALIES

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A computer has been developed for 2D analysis of total field of magnetic animalies due to arbitrary polarization. A prism of the different dip with arbitrary polarisation is used as a basic model. The results of interpretation are presented by co-ordinates and also by geometrical parameters and magnetic properties of sources of magnetic disturbance. Thus, there are the real preconditions for construction of the most reliable model in initial approximation. This method directed for prospecting of magnetic anomalies as sources over intrusions which may used for extraction of the mineral deposits. Also real possible to interpret the low anomaly for oil-gas-bearing structures. The method is applied to analyze the total field aeromagnetic anomaliess in North-West region of Ukrainaina Shield.

ESTABLISHMENT OF MAGNETIC SECULAR VARIATION NETWORK IN BELARUS

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In 1997, twelve magnetic secular variation (SV) stations on the territory of Belarus were established. These stations, together with the Magnetic Observatory Pleshtchenice create the Belarussian SV network. In 1996, the Magnetic Observatory Pleshtchenice was connected with European observatories Belsk (Poland) and Niemegk (Germany) by means of comparison measurements, performed using proton magnetometer and magnetometer D/I Flux. In summer 1997, the first set of 3 day observations was made on seven SV stations using the same magnetometers. The rest (5) stations will be observed in 1998. The Polish SV network consisting of 19 stations and 2 observatories - Belsk and Hel, and the Belarussian one will be both used for research of the magnetic secular variations on the territories of both countries. The main attention will be paid to the Northern part of the Precambrian Platform. It is also planed to include the Lithuanian SV network into common research.

A FAST DELTA "I" DELTA "D" SYSTEM FOR MEASUREMENT OF GEOMAGNETIC ELEMENTS

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The principle of the ASMO systems of the 1960's is used to measurethe module and pointing of the geomagnetic field vector in an intervalof 2 seconds. Originally the system used optically pumped Rubidium orCesium magnetometer and a big diameter Helmholtz coil pair. This instrumentwas suitable only for observatory use. Recently the magnetometer wasreplaced with low cost and low power Overhauser proton magnetometer andthe Helmholtz coil system with a compact spherical coil using twoperpendicular systems. The measuring system is operating from batteryand has an embedded microcomputer. The microcomputer controls the entireoperation with timing updated frequently from a GPS receiver. The measuringsystem was intended for observatory use but due to its easy installation andoperation it can be used for magnetic survey as well specially in regionwhere observatory data are not available.

MAGSAT MAGNETIC ANOMALY FIELDS FOR EUROPE AND ASIA

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Based on the Magsat data the scalar and vector magnetic anomaly maps over the European-asia area are constructed. Series of the intensive magnetic anomalies confirming magnetic inhomogeneity of these regions are extracted. The analytical models of the anomaly fields with the using the spherical cap harmonic analysis are produced. The modelling maps are camputed at the different satellite altitudes. It is shown the anomaly field over the Asia area is more smooth as against the crust anomaly field for the Europe. RMS is estimated to be about 2-3 nT for the Europe and only 1,5 nT over the Asia region. The profiles of the anomaly fields based on the satellite, aerostatic and aeromagnetic are produced, the field damping with the altitude is estimated. Comparison of the magnetic anomaly fields with the tectonic structure and with the other geophysical, parameters is carried out. It is made the supposition about the nature of the extracted magnetic anomalies from the Magsat satellite measurements.

DATA QUALITY OF REGIONAL MAGNETIC SURVEY

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There are some very interesting European projects including regional field magnetic surveys. The main peculiarity of these field works is that they will be conducted not in stationary observatory conditions and there are many ambient factors interfering with the collected data and so reducing drastically its quality. Two main sources make the most significant input to the error of magnetic field measurements: temporal and thermal dependence of the magnetometer readings. The estimation of these errors at existing magnetometers is made and some new results of their minimisation are considered. Some results of recent field magnetic surveys made in Finland and Western Ukraine in 1997 are presented and the influence of said error factors is discussed. New generation of low power autonomous three-components magnetic station LEMI-007 having automatic drift compensation and GPS-synchronisation and peculiarities of its design are presented. The possible approach to the development of low-cost high-class magnetometer including such applications as sea-bed and polar region long term magnetic survey is discussed and a possible approach to the calibration of magnetometer in the time of field experiment is proposed.

MAGNETIC ANOMALIES AND SECULAR VARIATION IN CENTRAL EUROPE

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Regional magnetic surveys or secular variation network measurements have been regularly carried out in most European countries during the last 50 years. The density of the measuring network and the time intervals between successive measurements vary from country to country. In many cases the number of measurements decreased with time due to increasing technical disturbances or personnel or financial reasons.
Secular variation models can be used to unify networks of different epochs. Reducing the values measured in different years in the various countries to common epochs leads to combined data sets for the region of central Europe.
Thus comparable magnetic maps and magnetic anomaly maps of three components can be modelled for different epochs, showing the secular variation and allowing an investigation on potential time variations of the anomalies. Whereas anomalies due do differencies in the magnetization of the earth's crust should not vary with time, there might be anomalies due to induction effects, that show time variations.

INITIAL RESULTS FROM ANALYSIS OF PERIODIC AND SECULAR VARIATION BY LabVIEW + HiQ.

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Traditionally a geomagnetic observatory was an isolated place where diligent scientists collected and tabulated in books the values of the observed components of the Earth's magnetic field. The possibilities to process the data were limited and the processing itself was separated from the observatory. Annual or monthly means as the "essence distilled" from the observed values were used for modelling. These series of means are contaminated by long-periodic magnetic fluctuations which is the source of uncertainity in the SV coefficients. In our days hourly means are available in digital form at the WDCs. Contemporary software packages for desktop PCs make possible sophisticated analysis "in situ". The paper presents how from short (12 hours) to long-periodic (11 years) fluctuations can be detected and eliminated from the magnetic time series. The method can produce more clean SV curves and it improves the accuracy of modelling.
LabVIEW and HiQ are the parts of the software package of National Instruments US. Add-on tool-kits like Wavelet and Filter Banks (WFB), Joint Time Frequency Analysis (JTFA), Digital Filter Design (DFD), etc. are available too. The later ones have been used in our work.

NEW COMPUTER DERIVED MAGNETIC ANOMALY, GRAVITY AND BATHYMETRY MAPS IN THE NORTH EURASIAN SHELF

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We present new digital compilation of the aeromagnetic, gravity and bathymetry data collected by Russian agencies in the North Eurasian shelf. In addition to recently collected digital data a lot of aeromagnetic data has been digitized in analogue or magnetic anomaly profile forms to be reprocessed and readjusted using interactive visualization, crossover analysis, navigational shifting of profile locations and directional filtering. Gravity and bathymetry data bases were compiled from the various maps, shipborh, and on-ice observations. In the Kara and Baretz Seas data sets were gridded at 5 km interval, in the East Eurasian Shelf existing data coverage allows to calculate only 10 km grids. The gridded data are presented as computer generated shaded relief color magnetic anomaly, bathymetry and gravity maps which provide new information for regional characterization of major tectonic elements of the Russian Arctic Shelf. The relief and deep structure of ot the basement were studied in applying 2D and 3D potential field modeling.

IGFR Model and Geomagnetic Repeat Station Surveys in Yugoslavia

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In period 1994-1996, survey on secular stations and the magnetic survey stations in Yugoslavia is done. the measurement on 19 secular stations during 1994 and on 100 the magnetic survey stations, during 1995 and 1996 are done. The results of geomagnetic field values measurements on secular station and the magnetic survey station are done with model IGRF, 1995 revision - IAGA Working Group V-8 (Barton C.E. et all; Geoph. Jour. Int.; 1996; 125; pp. 318-321) and the values which are get, are indicated as differences $\Delta T = T_{YU} - T_{IGRF1995}$.
The analysis of differences values ΔT on secular stations and the magnetic survey stations, which are aligned in ones regions of Yugoslavia.
The procedure of analyses of values and expanses allotment of differences ΔT, enables:
-to show the quality of selection of marks net in some regions, where the survey is done;
- to signify on existence some regional and local characteristic in allotment of ΔT differences of geomagnetic field in Yugoslavia.

SPECTRAL ANALYSIS OF THE MAGSAT GEOMAGNETIC FIELD

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Spectral analysis of the scalar and vector geomagnetic field measured by Magsat is carried out. Spectra were computed by the method maximum entropy. Spectral analysis of the satellite passes was made on all steps of the processing of the satellite data. Spectra for the scalar field and its vertical component are considered in detail. It is determined spectra of the dusk passes are more distorted than the spectra for the dawn passes and also spectra of the scalar field are more noisy by the magnetospheric- ionospheric currents than vertical componets. For the many passes spectra coinside after magnetospheric-ionospheric correction. It is shown that at the satellite altitude spectra to period $\sim$ 400 km are flat. For the larger periods a set of three spectral peaks within $\sim$ 500. $\sim$ 1000 and $\sim$ 3000 km are singled out. Extracted spectral peaks are connected most probably with three different classes of the magnetic anomalies having the different space parameters. Reality of the obtained results is confirmed by the data of the spectral analysis for the gravity field. From the results of spectral analysis of the Magsat geomagnetic field it was made a set of practical conclusions, connected with the processing of the satellite information.

AEROSTATIC SURVEYS OF THE GEOMAGNETIC FIELD AT THE STRATOSPHERIC ALTITUDES

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To obtain the Earth magnetic field at the altitudes (20-40 km) the launchs of the stratospheric balloons are used. Balloons supplied with a proton magnetometer, a GPS receiver and a board record are the unusual system for the carring on of the regional surveys at these altitudes. Unlike from stratospheric experiments carried out in a number of countries where the magnetic field was measured only, in Russia magnetic gradient measurements have been made with using system of three magnetometers simultaneously. A set of the gradient profiles was obtained for the European and for the Asia areas. Such data do not contain the variable fields and strongly are devided into the main and anomaly components. The anomaly field from these data is extracted usually by subtracting the value of the IGRF computed at each point of measurements. The analogical profiles were constructed from the Magsat satellite data. The comparison of the magnetic anomalies from the aerostatic and satellite surveys for the same territories showed agreements between these data. A set of intensive magnetic anomalies are isolated from the considered profiles. These data allowed to estimate the field damping with altitude and to carry out the modelling. The modelling showed the most problems of the anomaly fields can be solved by the using of the aeromagnetic, aerostatic and satellite data.

MAGNETIC SOURCES CHARACTERIZATION IN GUYANA INFERED FROM AEROMAGNETIC DATA ANALYSED WITH CONTINUOUS WAVELETS

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The high resolution aeromagnetic survey of French Guyana carried out in August-December 1996 by CGG/Geoterex (Compagnie Générale de Géophysique) is being interpreted by BRGM. As a contribution to enhance and characterize geological structures, we have applied the continuous wavelet technique developped by Moreau et al. (1995 & 1997) for the analysis of potential fields.
We have focused on the region between Cayenne and Kourou, where the sources geometry distribution is essentially 2D (made of dikes and faults).
The analysis of the set of profiles on focus has been done with 1D wavelets, resulting in a model for position, depth and homogeneity degree of sources of the anomaly fields. The use of 1D complex wavelets and 2D wavelets adds informations relative to azimuth and dip of sources, and orientations of the magnetization.
Geological maps and results from Euler deconvolution and the terracing operator are shown for comparisons.

AEROMAGNETIC STUDY NEAR GADARWARA AREA, AND ITS IMPLICATION ON THE NARMADA-SON LINEAMENT (NSL), INDIA

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The study of aeromagnetic data from Narmada-Son lineament (NSL), Gadarwara area identified parallel to sub parallel lineaments, traversing faults and intrusive bodies. A major anomaly, having a strike length of 15Km and width of 4Km is delineated near Gadarwara.The derivative filters enhanced the near surface features and the lineaments, where as,the high pass filter showed the absence of prominent short wavelength anomalies. The downward continuation mapped the near surface contact between exposed Precambrian units and recent alluvium. The dominant strike directions of the lineaments are proved to be NE-SW and NNE-SSW by using directional filters. Modeling using 2-D tabular bodies revealed, that the central anomaly is deeply rooted and concealed by alluvium. Its depth to the top is relatively shallow (250m) and estimations for other anomalies are more deeper. The linear pattern of the anomaly and the prominent magnetic lows suggest alteration. Thus, it is hypothesized, that hydrothermal fluids may help for the accumulation of metallic minerals along the structural traps. Estimations of depth by partitioning the grid gave approximate depths to the magnetic interfaces, and the thickness of the alluvium may reach 700m and above. The study culminated to an inference of a rift related intrusive body possibly associated with Cu-Ni sulfide mineralizations. It is envisaged that, local rift like structures may occur disrupted and concealed along the NSL.

DISTRIBUTION OF THE EARTH MAGNETIC FIELD ON THE TERRITORY OF SLOVAKIA FOR THE EPOCH 1995.5

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The paper deals with the geomagnetic field in Slovakia, derived from the magnetic survey made in the years 1993-1995. The D-, H-component and F were measured. The total number of points was 126. QHM, QD instruments and EDA proton magnetometer were used. The results, obtained in the field, were reduced to the epoch 1995.5 using the magnetogramms of the Hurbanovo Geomagnetic Observatory.

On determining reference fields from ground-based and satellite field data

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For the internal magnetic field the paper compares simultaneous reference fields from ground-based and satellite field data, respectively. Simultaneous SHA expansions of the same truncation index show different physical contents due to the different distances of the reference surfaces from the source region in the Earth's body. The satellite field model downwardly continued to the ground gives the relevant information as differences to the ground-based model. The procedure WIGCONT uses a regularizing criterion for the downward field continuation derived from the characteristics of the SHA, i.e. the physical contents of both the SHA models. Comparing them stepwise enables to evaluate the contributions of the model terms per degree and order of the SHA. The calculations are shown for the IGRF.

SE38 Long term global geophysical data products from remote sensing

Convener: Arino, O.
Co-Convener: Kerr, Y.H.

LASUR: THE LAND SURFACE REFLECTANCE DATA FOR 1989-1990

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The data processing we have applied to global weekly AVHRR time series is presented here. Two years, 1989 and 1990, of NOAA 11/ AVHRR/ GVI data have been processed to improve the radiometric quality of these satellite data, in order to derive long term global geophysical products such as terrestrial primary production, carbon fluxes, LAI ... at a global scale with better accuracy. The processing includes three steps: i) calibration of digital counts into top of atmosphere reflectances, ii) correction of the effects of the atmosphere, and iii) screening of noises due to clouds and erroneous data.
The generated product (named LASUR for LAnd SUrface Rflectances) contained the top of atmosphere and surface reflectances in visible and near infra red channels, a flag channel which indicates the radiometric quality of every pixel, the geometric configuration (solar and view zenith angles, relative azimuth), the thermal channels T4, T5, and surface temperature, and the vegetation index NDVI.
The LASUR data set is available from the authors.

World Fire Atlas with AVHRR and ATSR data

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A Remote Sensing "*Fire Product*" has been developed to answer to the requests of the land and atmospheric chemistry user communities. Content, format and algorithm of the "*Fire Product*" are described. More than ten thousand NOAA-11 AVHRR after-noon passes have been processed in order to cover at best South America, Australia and Africa for several years. Prototyping of the "*Fire Product*" with night time acquistion of the ERS/ATSR has also been performed. All monthly and yearly fire maps, detected fire coordinates files, are loaded on a WEB server to allow free public access through the INTERNET: http://shark1.esrin.esa.it. In order to cope with the multiple user requirements, an interactive tool to generate the fire maps for selected periods and time has been developed on CD-ROM and WEB server.
The quasi operational data acquisition, processing and user access of the "*Fire Product*" is described in this paper.
Emphasis on use of multiple global geophysical data set together with the "*Fire Product*" for environmental purposes will be given.
First "*Fire Product*" uses demonstrated the interest of the product for atmospheric chemistry, forestry and land use applications and researchs. Cross uses of multiple global geophysical data set will ber highlighted.

The "Global land Land 1km AVHRR data set" project: ESA activities in data collection, processing and distribution

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Based on the Intenational Geosphere Biosphere requiremets, a joint project among NASA/USGS, NOAA, ESA and other organization, for the compilation of a global land AVHRR data set at 1km resolution was set up. During these 6 years of project, since April 1992, ESA/ESRIN has been having an active role in collecting and exchanging data with the USGS/Eros Data Center and in setting up archiving, processing and distribution facilities at ESRIN. More then 70 000 satellite passes have been collected since the beginning of the project and a copy of the "1km" data set high level processing chain developed by EDC has been installed at ESRIN for sharing part of the huge data processing required for generating multitemporal NDVI global maps at 1 km resolution. ESA/ESRIN has set up a server accessible from the network for distributing Global Land AVHRR 10-days poducts derived from the "1km" data set. The operational capacities required to run such a big project, the preliminary analysis of the product generated and the server access statistic will be discussed. This project is seen in the Agency as a forerunner of a similar project to be initiated with the ATSR data on board of the European Remote Sensing satellite.

PRODUCTION OF TROPICAL FOREST DISTRIBUTION MAPS USING REMOTE SENSING DATA AT A GLOBAL SCALE

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Of major concern is the issue of forest distribution. New information technologies make possible the development of more advanced systems of data gathering and analysis which can accurately inform of current status of the forest cover over the tropics.
In the framework of the TREES project, techniques for a global tropical forest inventory were developed. These techniques made use of an extensive satellite data set analyzed in an ad-hoc manner. The TREES concept was to make a wall to wall coverage using highly repetitive observations at low resolution (NOAA AVHRR data). The main product consists of the global map of tropical forest cover at 1 km resolution. Comparison with reliable conventional forest cover maps has shown that a good level of agreement is obtained for most of the forested regions. This global assessment has been further calibrated using high resolution image maps on selected sites.
The latest developments made in this framework such as the analysis of new relevant data (ERS-2 ATSR) in order to assess the conditions in the forest areas at the pantropical level will be presented.

AN OPERATIONAL SCHEME FOR CLOUD CLASSIFICATION OVER LAND USING METEOSAT IMAGERY

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Cloud cover is an important parameter closely linked to type and intensity of precipitation events, but it is especially difficult to have a reliable extensive coverage based on classical methods of observations. On the other hand, because of its high resolution in time, Meteosat imagery provides an adequate tool in estimating variability of cloud cover at the regional and local levels.

In this communication we present a Project currently being developed at the University of Lisbon within the framework of MEDALUS III aiming towards a long-term assessment of occurrence and variability of three types of clouds (high, mid and low layers) over Portugal, based on IR Meteosat imagery.

The dataset consists of a sequence of hourly images (VIS, IR and WV) covering the month of February 1996, as well as of three-hourly observation of cloud types and hourly values of precipitation at 15 synoptic stations in Porugal.

Cloud covered areas are identified and IR pixels are classified into three different layers (low, middle and high clouds) using a spatial coherence method, which was adapted for the present purpose. Obtained results were statistically validated based on dispersion diagrams (IR vs. VIS and IR vs. WV count values) as well as on scores from contingency tables of cloud types (synoptic observations vs. Meteosat classification) at synoptic stations in Portugal.

ERS-2 RADAR ALTIMETER: 3 YEARS OF RESULTS

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In order to ensure the quality of the ERS-2 mission over its lifetime and the best continuity at product level between consecutive missions such as ERS-1 or Envisat, geophysical and instrumental performance monitoring (long term and short term) are carried out in ESRIN/PCS. These activities cover all steps of the processing chain from the mission planning to the sensor performance, passing by the data acquisition to the processing and dissemination, from the point of view of Quality Control. This task requires today a more and more careful analysis of all the error sources still to satisfy the initial mission requirements but also to answer to new requirements from the scientific community. The study of sea-level rise is such an example, which even pushes the Radar Altimeter to the limits of its specifications. This paper describes the performance status of the ERS-2 Radar Altimeter instrument after almost 3 years of activity, with emphasis on the instrumental part and its associated corrections.

MAPPING SOLAR RADIATION FROM METEOSAT IMAGES WITH THE IMPROVED HELIOSAT METHOD.

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Solar energy is essential for our planet and the life. Its knowledge is required in many fields, such as agro-meteorology, renewable energies, climatology, oceanography... Once properly processed, images of geostationary satellites such as Meteosat provide instant maps of the solar irradiation available at ground level. Such maps are very valuable for the knowledge of the geographical distribution of the solar radiation. Our project aims at establishing a climatology of the solar radiation for Europe, Africa and Atlantic Ocean, using more than ten years of Meteosat data. The first phase of this research is the improvement of the Heliosat method in several aspects: accuracy, robustness and reliability. This method is presently used worldwide. It makes use of meteorological satellite images to derive a cloud index, which characterises the transmittance of the atmosphere. This cloud index is then related to the atmospheric clearness index, which provides hourly global irradiation. Some modifications of the original method are proposed: the calibration function (relationship between the digital count and the amount of energy received by the satellite), the modelling of the radiative transfer under clear sky (taking into account the Linke turbidity factor), the assessment of the apparent albedo of the brightest clouds used in the computation of the cloud index, the modelling of the radiative transfer for overcast skies. A validation of these modifications is done by comparing the estimated hourly values of global solar radiation with ground measurements.

GLOBAL LAND SURFACE TEMPERATURE RETRIEVAL FROM NOAA AVHRR DATA

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The study presented here is related to the development of a land surface temperature processor to be applied to NOAA AVHRR 1 Km global data set. For this purpose we started by considering all the available algorithms suitable for the data (i.e. ten day composites of noon AVHRR data with channels 1,2,4 and 5). The algorithms were tested with two approaches : a « theoretical » one where a radiative transfer model is used to generate top of the atmosphere brightness temperatures which are then used to infer surface temperature with the algorithms. This approach allows to analyse the sensitivity to surface and atmosphere parameters. The second approach consisted in comparing the results of the algorithms with ground data. Once the algorithms were selected, they were used on the actual AVHRR global 1 km data set with a validation scheme and analysis of behaviour over « difficult » targets (snow/ice/clouds) and over one year. A particular emphasis is given on perturbating factors such as emissivity and atmosphere. We will present the results of the inter comparison and the related problems together with the processor output.

METHODS FOR LAND COVER DYNAMIC MONITORING USING THE GLOBAL LAND 1-KM PROJECT AVHRR DATA. APPLICATION TO MOROCCO.

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The principals objectives of the present paper is to contribute as far as possible to the detection and monitoring of land surface degradation using satellite data. Generally, reduction and loss of fertile topsoil induce to vegetation degradation which is one of the most important signs of the desertification process. With this in mind, we address this problem by applying theoretical models to obtain from satellite data biophysical indicators such as: land surface temperature (LST), and NDVI, and by analyzing the spatio-temporal dynamics of these parameters. Morocco has been chosen as a convenient area of study. Reasons for this choice include, its small size at the resolution of current satellite global data-sets and its high environmental diversity. A multi-temporal analysis has been carried out from NOAA-AVHRR data provided by The Global Land 1-km project NOAA/NASA. This data set allowed us to discriminate between different characteristics zones using as mapping criteria the annual average of NDVI. Two methodologies are proposed for the monitoring of land cover dynamic: one is based on the form described by the evolution of LST and NDVI in each area and the other analyzed the slope of the line defined by the months of the maximum NDVI, and the minimum LST.

SE38

Long-term change detection of forest decline in the Kola Peninsula

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The central Kola Peninsula, Northern Russia is one of a few places in the world with a large-scale forest damage attributed to a single pollution source. Approximately 60 years of the operation of the 'Severonickel' copper-nickel smelter have markedly changed the natural environment. Within a 100-km distance from the smelter there is a gradient of vegetation condition from industrial desert to the undisturbed background. The objective of the study was to quantify the long-term changes in the boreal forests based on analysis of declassified high-resolution spy satellite pictures (Corona) from 1964 and recent medium-resolution satellite images IRS-1 C Pan and Landsat-TM from 1996. The image data ~~were geometrically~~ matched to a common projection and radiometrically enhanced to highlight the changes in vegetation cover during the 30-year period. A quantitative assessment of changes in forest cover is carried out by means of point-wise visual interpretation in an objective systematic sampling design. The interpretation is supplemented with information from topographical maps. The results of interpretation is compared to modelled SO_2 concentration in the area and to observations on long-term monitoring plots.

WHAT ARE THE CANOPY BIOPHYSICAL VARIABLES THAT CAN BE ESTIMATED FROM LARGE SWATH SATELLITE DATA?

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A synthetic top of canopy BRDF catalog of homogeneous canopies is built thanks to a well known radiative transfer model (SAIL). A large range of models parameters (LAI, mean leaf inclination angle, hot spot, leaves and soil optical properties) is considered for different dates and latitudes. The directional and spectral sampling is done according to the VEGETATION instrument characteristics. We focus on several biophysical variables of interest such as nadir gap fraction, mono and bi-directional gap fractions, canopy integrated chlorophyll content ($LAIxC_{ab}$). LAI and f-APAR. We investigate the interest of using neural networks instead of classical vegetation indices for the estimation on these variables. This estimation requires two normalized input parameters (nadir and hemispherical reflectance) in the three wavebands considered. They are obtained by inverting the Walthall linear BRDF model on the VEGETATION reflectance data. Results show good performances of the neural networks for the estimation of fAPAR, nadir gap fraction and canopy integrated chlorophyll content. The estimation of LAI, monodirectional and bidirectional gap fractions is less satisfactory.

01 Open session on physical properties of geomaterials (posters only)

Convener: Urai, J.L.
Co-Convener: Huenges, E.

GEOPHYSICAL INVESTIGATIONS OF THE CLÉRY FAULT, VERCORS, FRANCE

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The Cléry fault is a major strike-slip fault in the southern part of the Vercors massif (French Alps) which has been active during the last 10 to 20 million years. During that period, the two fault blocks have been horizontally displaced by about 3.5 km according to geological observations. We present the results of seismic, transient electromagnetic and magnetotelluric measurements performed across the Cléry fault in order to investigate the fault zone structure and its physical characteristics.
Our seismic experiments were designed to observe trapped waves in the 40-meter wide fault gouge by using active seismic sources and geophones deployed across the fault zone with a spacing of 5 m. Modelling of the observed seismograms shows that the high amplitudes observed within the fault zone, especially close to the fault sides, can be explained by soft material indicative of water circulation near the fault limits.
The inversion of magnetotelluric data acquired along two profiles crossing the fault shows a NW-dipping resistive layer covered by conducting sediments 20 to 70 m thick that end abruptly near the NW flank of the valley. This suggests a small vertical component of motion about the Cléry fault. Induction vectors show that the Cléry fault itself is not a large conductivity anomaly since the vectors point towards the ESE at high frequencies, likely in response to water springs. Moreover, these vectors point towards the SW at lower frequencies, suggesting a conducting feature SW of the valley that could be associated with the SE-striking Combe Male fault.

INFLUENCE OF CHEMICALLY ACTIVE FLUIDS ON FAULT SLIP

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Recent geophysical measurements have demonstrated that the average shear strength of active continental fault zones is far lower than predicted from traditional brittle-plastic strength envelopes. The inferred weakness is believed to due to either a reduction of sliding friction by elevated fluid pressure, or to the action of pressure solution related deformation processes in the fault zone. However, these chemically enhanced deformation processes are poorly understood. In this contribution, experiments on the effect of fluids of different composition on fault gouge strength are reported. In the experiments, halite is used as wall rock and gouge. Halite is used as a rock analogue, because pressure solution processes are prominent in halite under easily accessible experimental conditions. Various NaCl-saturated water/methanol mixtures are used as pore fluid. Experiments are conducted using a room temperature, atmospheric pressure ring-shear apparatus. The apparatus allows control of normal stress and sliding velocity, and monitoring of shear stress, compaction/dilatation, shear displacement, and acoustic emission activity. It was observed that addition of NaCl-saturated water leads to rapid gouge compaction and a two- to threefold increase in fault strength. In addition, sliding behaviour changes from stick slip to stable sliding. Increasing the methanol content of the fluid has the effect of diminishing the strengthening effect. These results suggest that the action of pressure solution alone does not cause fluid-assisted fault weakening, and other factors, like presence of clays, mineral reactions, or elevated fluid pressure, may be needed.

VARIATION IN ELASTIC ANISOTROPY IN ROCKS DEFORMED UNDER HIGH PRESSURE AND UNIAXIAL COMPRESSION

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The longitudinal wave velocities are measured in sedimentary rock samples (sandstone, aleurolite, limestone, dolomite) subjected to uniaxial compression (up to their destruction) at a confining pressure of up to 120 MPa. The samples were collected from both holes drilled in various oil- bearing fields and outcroppings. The measurements indicate the occurrence of and variation in the elastic anisotropy, as well as its relation to dilatancy, under the conditions of both the complex stress state and differential stress relaxation. The revealed specific features related to anisotropy suggest an additional porosity in the rocks, caused by deformation. An increase in the P-wave anisotropy may serve as a precursor phenomenon of the main rupture. Upon increasing, the anisotropy may be decrease, if the velocity measurements are made outside the main rapture zone.The experiments show that, because of cracking, the induced elastic anisotropy is retained after relaxation of the additional stress under high pressure, and the P velocity decreases as compared to the undeformed samples.

ATOMISTIC SIMULATION OF QUARTZ AND CRISTOBALITE AT HIGH TEMPERATURE.

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Recent experimental measurements demonstrate weak dilatation of the β-phases of cristobalite and quartz at high temperature. We have previously observed some decrease of the unit-cell volume near to the melting point. The dynamics of the structures of these phases at high temperature are still are poorly undestood. Study of these polymorphs using free-energy minimisation and moleculare dynamics techniques will be presented. The free-energy minimisation approach allows the structural parameters to be varied until the configuration with lowest energy is achieved. The free-energy is incorporated by including lattice dynamics wich also allows the calculation of thermodynamic properties at different temperatures. We show the good agreement between our experimental data and calculation for the low-temperature phase of cristobalite. Problems occur when the high temperature phase is simply an average of one or more accesible structures and in this case molecular dynamics provides a more reliable simulation tool. The results of molecular dynamic simulations of quartz and cristobalite show that these are dynamical disorder phases and that β-cristobalite is the average of tree possible different modifications of α-cristobalite. In summary, coupled with reliable interatomic potentials these techniques provide a valuable link between the atomistic and thermodynamic behaviour of minerals at high temperature and pressure.

INFORMATIVITY OF MICROSTRUCTURAL INVESTIGATIONS OF ROCKS UNDER HIGH PT-CONDITIONS FOR STUDY OF PROCESSES OF EARTHQUAKES PREPARATION.

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In present the high pressures apparatus intending for measurements of physical characteristics of rocks doesn't allow to study the structural and textural changes of geomaterials during loading processes. It is possible made only in the diamond chambers. But very small volums of samples in it are of no interest to problems of seismology. The using of neutron diffraction method showed that the changes in the physical parameters caused by a deformation are associated with the structural changes in samples. The experiments with marbles were shown two phase transformations remarked at 0.4 Gpa and 1.6 Gpa by change of deformation, elastic waves velosities and attenuation. The texture analysis conducting of neutron diffraction method was shown that changes of form of texture and its turning take place at first and second transformations under loading.

MODELING TRANSPORT PROPERTIES OF CRUSTAL ROCKS DURING PROGRADE METAMORPHIC EVENTS

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Prograde metamorphic reactions releasing water from mineral structures occur in a different tectonic environment in response to increases in temperature. The most reliable conditions for dehydration of crustal rocks at the depths 15 - 30 km are T=300 C (dewatering of S-type granites), then interval 300 - 600 C (a set of reactions in metapelitic rocks) and T= 700 - 750 C (breakdown of hornblend). The main factor determining the transport properties of ocks during metamorphism is the content of interconnected fluid phase (FPh). The considered model corresponds to the case when the FPh is a product of reaction between two neighbouring minerals of a- and b-type (for instance, muscovite and chlorite) creating an elementary reaction volume (ERV). Numerical study is based on the calculations for a system of randomly distributed cubic grains of two different minerals (total number of grains is equal to one million). Under assumption that the connectivity of FPh is determined by the connectivity of ERV we were able to calculate the content of interconnected and isolated parts of FPh, mean length and number of percolation paths, and estimate on this base the mean values of electric conductivity and permeability for different concentrations of reacting minerals and released FPh.

LIMITATIONS IN IDENTIFICATION OF LAKE SEDIMENT LAYERS BY USING PRECISE GEOELECTRIC SOUNDINGS

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In this paper the near-surface (to a depth of 3m) layer-resolution power of geoelectric soundings, carried out at the surface with the possible greatest precision (20 data/decade; mm-range horizontal geometry in case of AB distances shorter than 6.4m; a combination of potential electrodes at the surface and at a depth of 40cm) is illustrated in a geological environment of a lake, where the eutrophysation process is in progress. (The measurements in the Lake Fertő (Neusiedlersee) region situated just at the border between Austria and Hungary were carried out in 1997 frames of two bilateral cooperations.) The inverted apparent resistivity data with different core sample physical properties, such as magnetic susceptibility, humidity and core sample resistivity have been directly compared. Local inhomogeneities and thin layers are not seen from the surface, while the robust and continuously changing layer transitions can easily be resolved by geoelectric inversion methods, allowing smooth layer transitions. These methods seem to be superior to the classical few-layer inversion techniques. In such circumstances the lateral variation of layering can be satisfactorily followed from the surface.

ALTERATION AND MASS TRANSFER ALONG THE GSJ BOREHOLE PENETRATING THE NOJIMA EARTHQUAKE FAULT

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We clarified the relationships between fluid activity, alteration and deformation for the samples from the GSJ (Geological Survey of Japan) boreholl penetrating the Nojima fault which was activated at the 1995 Hyogoken-nanbu earthquake. The borehole is 746.7m deep and the coaxial fault zone is from 623.3m to 625.1m depth, where fault gouge is distributed.

Two major types of alteration activity (type A and B) can be recognized from alteration mineral assemblages and a fluid inclusion study. Characteristic minerals are chlorite and laumontite for type A alteration and smectite and carbonate (calcite, siderite and dolomite) for type B alteration respectively. Type A alteration covers the whole core and it probably occurred during deuteric stage or porphyry intrusion. The alteration temperature is estimated to be about 150 to 200℃ from occurrence of laumontite and fluid inclusions with higher homogenization temperature. Type B alteration overlaps type A alteration and the main distribution is restricted within fault zone. The alteration temperature is probably lower than type A alteration. This alteration is due to very recent activity as carbonate crystal is euhedral in shape even in the coaxial zone. Thus, type B alteration probably results from fluid migration related to fault activity.

MEASUREMENTS OF DIFFUSION IN UNCONSOLIDATED CLAYS WITH THE AID OF RESISTIVITY TOMOGRAPHY

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Diffusional transport is the most prevailing transport property in clays, although the hydraulic permeabilty is very low. This is the reason for the development of a non destructive testing method of the diffusional parameters in clays. The underlying petrophysical parameter for diffusion is the formation factor, which is very low (1.5 - 5), resulting in the high conductivity of unconsolidated clays.
Electrical resistivity tomography (ERT) provides a means for the study of diffusion in soils. A modified SIRT algorithm, which includes forward modeling, is the basis for the calculation of the tomograms from automatical dipole-dipole electrical measurements on cylindrical samples in the laboratory.
A bubble of concentrated salt solution (NaCl and KCl) was injected into the centre of the measuring plane. ERT was used to monitore the diffusional spreading of this conductive source. The time dependent equiradial mean values of conductivity were fitted to the solution of the diffusional equation for a point source, yielding diffusional constants about $0.5 \cdot 10^{-10}$ m^2/s. This is in accordance with electrical measurements of the formation factor.
This method can also be applied for in-situ tests.

THE ANOMAL CHANGES OF THE PHYSICAL PARAMETERS OF CLINOPYROXENES AT HIGH PRESSURES.

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The longitudinal waves velocities and decrement of volume of clinopyroxenes were defined at high pressures up to 1.5 Gpa in the cylinder-piston type apparatus. The samples were been cut out along one direction of the extending of silica-oxygenous combinations. The experiments were been carried out successivily at high pressures up to 0.5 Gpa; 1.0 Gpa; 1.2 Gpa; 1.5 Gpa on the different samples. It is istablished that the most anomal changes of the physical parameters remark at high pressures up to 0.5 Gpa. They associated with brittle distruction of the clinopyroxenes. Such behaviour of rocks can be of cause of the distruction processes in the Earth.

DEEP PETROPHYSICAL MODELING AND NEW PRESENT TENDENCIES OF ITS DEVELOPMENT

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Most anomalous effects seen in the observed geophysical fields, processes and phenomena are mainly caused by deep changes and uneven distribution of mineral substance physical properties in respective thermobaric conditions of the Earth's interior. The cognition of these phenomena is a very important problem in studying its content, state and structure.This stimulates new recent tendencies of the use of experimental petrophysical PT information in setting up respective models of deep geologic medium. We propose combined approaches and new methods of the construction of regional petrophysical lithosphere models based on a systems analysis of laboratory,field and borehole data. As examples some deep petrophysical models of the precambrian Ukrainian Shield are presented.

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ELECTRONIC PROPERTIES OF MINERALS RELATED TO THE EARTH'S LOWER MANTLE

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A relation among the "critical" density value d^x, average first ionization potential per free atom $\langle Uo\rangle$, and mean atomic weight $\langle A\rangle$ for semiconducting modifications with the zero-energy gap of some silicates and oxides related to the mantle material is suggested. The theoretical considerations are based on the Lorentz electron theory of solids. The eigenfrequency νo of elementary electron oscillators in energy units $h\nu o$ (h is Planck's constant) is identified with the energy gap of a solid phase. It is assumed that only the electric Lorentz field plays an important role within the mineral structures. This relation is of the form

$$d^x = \frac{\langle Uo\rangle^2 \langle A\rangle}{276.787} \quad g/cm^3,$$

where $\langle Uo\rangle$ and $\langle A\rangle$ are expressed in eV and g/mol, respectively.

THE ELASTIC CONSTANTS AND ANISOTROPY OF METAMORPHIC ROCK VELOSITIES OF KOLSKAYA SUPERDEPTH WELL

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The elastic constants of gneises and amphibolites has determined by invaiant-polarization method on core samples of Kolskaya superdepth well from depth of 7600-9500 m. The elastic symmetry of rock textures is triclinic system. Using inversion data of the elastic costant azimuthal dependence were given pole diagram of the mineral and microcracks orientations. The microcrack orientation provides information on the stress field, which response for them formation. The relaxation of residual stresses from core samples is carried out by disclosure of microcracks. The value of tectonic stresses on these depthes is equal 700-1000 mP. The nature of seismic anisotropy of the upper part of the earth continental crust is describe.

THE PROBLEM OF MEASURING THE DENSITY, ULTRASONIC VELOCITIES AND ATTENUATION IN ROCKS, USING THE PISTON-CYLINDER APPARATUS UP 2 GPA

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In measuring the physical properties of rocks in a solid-phase apparatus, the problem of determination of the pressure and stress state of a sample arises. Most frequently, a nonhydrostatic stress occurs in such apparatus. However the hydrostatic stress state can be achieved taking into account the effect of dissipative forces on the pressure. A method of cyclic loading of the high-pressure cell with the variable direction of piston movement efficient in studying the phase transitions accompanied by a change in volume. The method allows the equilibrium state to be reached efficient in the phase transformation process, i.e. the condition of a new phase is "frozen". The hydrostatic pressure can be achieved for a single- phase state . The method was applied to study the phase transitions in RbCl and calcite. The longitudinal and shear wave velocities were measured in these materials by the pulse transmission method. The attenuation was determined by FFT method from digital records of pulses. Also, their density was measured. All these values were determined for the low- and high-pressure phases in a different phase concentration

PHYSICAL PROPERTIES OF FAULT ZONES IN ESTONIAN EARLY PALAEOZOIC SEDIMENTARY BASIN

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The fault zones in the crystalline basement of Estonia are usually reflected by zones of disturbances in the shallow sedimentary basin. Usually the linear dislocations are represented by monocline folds complicated by fracture zones, accompanied by carst processes, dolomitization, sulphide mineralization and leaching of carbonate rocks. During exploration the fracture zones are usually located by low-resistivity anomaly zones. Petrophysical properties of fracture zones were studied by logging data and in laboratory. Alteration of the fractured rock properties were revealed at resistivity logs and at the natural gamma-ray logs by increasing of natural radioactivity caused by altered rocks with significant increase of total iron content, which can adsorb radioactive elements. In the case of carst zones the logging curves may be greatly changed and they may show that marker high radioactive layers are destroyed. The measurements of the core samples from the low-amplitude fracture zone in the Ordovician rocks revealed increase in secondary porosity of carbonate rocks, caused by fracturing and leaching associated with dolomitization. This caused the decrease in bulk density, seismic velocity and alteration of electric properties: decrease in apparent resistivity and dielectric constant and increase in induced polarization. Dolomitization in the fracture zone caused increase in total iron content, magnetic susceptibility and grain density.

TEXTURE ANALYSIS IN GEOPHYSICS

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Modern texture analysis using neutron diffraction in combination with petrophysical investigations permits to fulfil the reconstruction of the paleotectonic stresses acting during various stages in the evolution of a tectonic block. To reconstruct the possible form of the quartz and xenolith deformation state computer simulation was performed for various sets of slip systems. By comparing theoretical and experimental pole figures the strain paths during paleodeformation have been established. Some problems of the crystallographic texture formation in quartzbearing rocks with piezoelectric properties are considered. The crystallographic models of ideal texturized quartz aggregates are suggested which are correspond to rocks with the definite symmetry of piezoelectric properties. Based on the Taylor's theory which was modified for accounting the effect of a deformation velocity on the flow limit, the simulation of texture formation of high-temperature quartz has been fulfilled. Methods of texture analysis and mechanics of solid body were applied to solving the problem of mechanical state of a medium with an anisotropic inclusion whose symmetry of elastic properties varies due to texture transitions.

PETROPHYSICAL PROPERTIES OF ESTONIAN EARLY PALAEOZOIC CARBONATE ROCKS

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Petrophysical properties of argillaceous to varying degree limestones and dolomites were measured on core and outcrop samples together with their chemical composition. Primary and secondary altered rocks were studied. The most important factors influenced the variability of studied density, seismic, electrical and magnetic properties are the clay content, dolomitization and porosity. Porosity of primary and secondary origin may occur in the studied carbonate rocks. Clay content has high correlation with porosity, which was interpreted as primary. Secondary porosity was investigated in the fracture zones and in the secondary dolomites. Five groups of secondary dolomites of different age and genesis (widespread and associated with fracture zones) were studied. The variability in properties was revealed for limestones with different clay content and for dolomites of different origin. Generally clay content and porosity control alteration in electric properties, bulk density and velocity of rocks. Magnetic susceptibility increases with clay content and owing to dolomitization. The highest porosity and magnetic susceptibility were measured in marls and secondary dolomites. Dolomitization also causes increase in grain density of rocks. Relationships of velocity with porosity differ for limestones and dolomites. The groups of limestones with different clay content and studied five groups of different origin dolomites were characterized by combination of specific values of petrophysical and geochemical parameters.

WEAKENING PROCESSES WITHIN CONTINENTAL FAULT ZONES

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Many continental faults and shear zones are repeatedly reactivated after long periods of quiescence (>1 Ma). This requires long-term weakening within faults where they cut through the main load-bearing region of the crust around the frictional - viscous creep (F-VC) transition. Ancient examples of reactivated faults often preserve exhumed sequences of fault rocks in which mid-crustal processes may be examined directly. Our field and laboratory-based studies of examples developed in basement rocks of the N Atlantic region suggest that weak faults are most likely to form due to fluid-related reaction weakening processes. Influx of hydrous fluids is usually facilitated by pervasive fracture dilatancy during cataclasis in regions immediately above the thermally-controlled equilibrium F-VC transition. Load-bearing framework and chain silicate mineral phases in the protoliths are extensively altered to fine-grained aggregates of weak phyllosilicate that rapidly collapse leading to the development of strongly foliated phyllonites that deform by viscous creep mechanisms. Provided the phyllonites are sufficiently well developed to form an interconnected network occupying about 20% of the total rock volume, this leads to an effective shallowing of the F-VC transition along the fault zone and to a weakening of the crust, possibly by several orders of magnitude.

GRAIN-TO-GRAIN INTERACTION AND IT'S INFLUENCE ON RHEOLOGY OF ROCKS. (NUMERICAL MODELLING).

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Rocks are very complex aggregates of different minerals of wide varieties of shapes and sizes with different properties. It's still not clear how they are interacting to each other creating that response on the load, which can be measured in laboratory. This presentation is devoted to 2D numerical simulation of interacting grains and estimation their influence on rheology of polycrystal rocks. Each single grain is considered to be isotropic. Continuum approach coupled with finite difference method is used to model nonlinear (power law) granular medium. Different instances of minerals are mapped in the model by different rheologic parameters. In order to get proper resolution grid size was 900X300 that require the calculations to be performed on supercomputers. Result of numerical modeling shows that rheology of aggregate differs from rheology of constitutive grain and key feature in this magic conversion is grain boundary interaction. It becomes negligible if phase density of grain (in system inclusion-matrix) is below ~ 0.125. Nonlinear boundary response of the crystals causes nonlinear behavior of the polycrystal aggregate even each separate crystal obeys Newtonian rheology. Each grain changes its shape while deformation in its turn that affects on cumulative rheology making it time-dependent. Model allows estimating an influence of grain size on rheology of rocks.

NUMERICAL SIMULATION OF THE TIDAL EFFECT

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The dominating natural force acting on an offshore reservoir is induced by fluctuations in the sea level. This variation is mainly a consequence of tidal effects. The cyclic variation of the sea level will have an effect on both production and observation wells. Many well tests from the North Sea are clearly influenced by the tidal effect. The main objective of this work is to develop a new methodology for the interpretation of the reservoir response to changes in the sea level. The response of the reservoir to tidal effects is a cyclic compression/decompression of the rock/fluid system. The most important parameters which are reflected in the response function are compressibility, permeability, porosity, reservoir size and compaction modulus.The project lies in the interface between reservoir engineering, rock mechanics and mathematics. The results imply that improved conceptual and mathematical models will lead to enhanced methods in reservoir monitoring. Reservoir management and control based on sea level fluctuations will be attractive from an economic point of view since only natural forces are employed.

STILE OF BUCKLES IN ANALOGUE "ROCKS" WITH DIFFERENT RHEOLOGIES

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Rheology describes the mechanical response of a material to the applied forces. We show experimentally how the rheology of materials influences the characteristics of structures. Many natural folds initiate by buckling under a compression close to parallel to layer boundaries. We study shape and growth rate of folds by shortening competent layers of different materials embedded in a weaker ductile matrix.Two types of materials with strain-hardening and a strain-softening behaviour were used to represent the competent layer embedded in the less competent matrix.We investigated the character of deformation by analysing the shape versus strain curves at the same time as the folding instability develops. In particular, we examined how the degree of strain-hardening or strain-softening influences the shapes and growth rates, the selection of wavelength with thickness, and the degree of layer parallel shortening during the growth of single layer folds. We also modelled multilayered folding and examined the change of fold shape with spacing of the competent layers, the formation of chevron folds in alternating layers with different rheology and the mechanism of nucleation and propagation of conjugate kink folds.
Our experiments show that the degree of strain-hardening/softening affects not only the fold geometry, but also controls the deformation mechanism. It may be possible to infer the qualitative rheological properties of natural folds and the conditions of their formation by studying the process of folding in analogue models.

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DC-GEOELECTRICAL DEEP SOUNDINGS IN COMBINATION WITH MODERN INVERSION TECHNOLOGIES: A TOOL TO INVESTIGATE GEOLOGICAL STRUCTURES

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Electrical Resistivity Tomographie (ERT) is a well established DC-geoelectrical survey method in small and mid scale explorations. We transformed the measurment scheme to carry out a large scale experiment to investigate the earth's upper crust. The surroundings of the bore of the German Continental Deep Drilling Project (KTB) was choosen as test field. The geometrical setup follows a 22 km dipole-dipole-profile. To realize the concept of simultaneous multichannel registration of the scalar electrical potential at 44 dipoles, we used independent transmitting and receiving units. The measured data deliver apparent resitivities which were inverted to a two dimensional model of the resitivity distribution to a depth of 4 kilometres. It was possible to detect two high conductive structures with steep inclination. They are expected to be major fault zones embedded in a metamorphic body. The rather low resitivity with $\rho < 1\ \Omega$m can be explained by the existence of graphitic minerals or electrolytic fluids. With the method of the multichannel DC-geoelectrical survey combined with tomographic inversion schemes it is possible to obtain detailed structural information reflecting past and recent tectonic processes.

COMPARATIVE VALUES FOR ENVIRONMENTAL PARAMETERS IN A HISTORICAL BUILDING

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There are several external agents who stimulate the stone's alteration, the atmospheric agents in particular; the ones that cause thermal effects and water's actions are outlined against the others. In orther to establish their significance, in this work results of the daily and seasonal fluctuations of the meteorological and environment paramters that contribute in these effects, as the temperatura and the humidity are presented. The work has the later objetive to determine thermal and higroscopic seasonal and daily cycles on a specific area in a historical building, as is the Burgos cathedral, who is situated in the city centre.
The thermohigrometric measurements have been carried out with contact thermistor probes, type PT100 for the surface temperature and with electronic sensors for the temperature andrelative humidity. The instrumental used for the atmosphere are a piranometer of global radiation solar, type CM-6B and rain monitor for electrical identification at the beginning and the end of rain.
The measurements carried out during several selective periods in 1997 and on different locations in the monument. Results of values have been compared for surface and air temperatures, and relative humiditys, in differents episodes and under several meteorological conditions.

ELECTROMAGNETIC TECHNIQUES FOR FAULT ZONES MAPPING

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Fault zones manifest themselves by low specific electrical resistivity ρ, high ρ anisotropy, high dielectric permeability and induced polarization. This characteristics are used for faults mapping at different scale. Regional deep faults are mapped by extended frequency band MagnetoTelluric Sounding (MTS), which allowed to map in central Ukraine a network of deep faults with discrete inherent azimuths. For the faults mapping at intermediate scale we have developed a version of airborne frequency sounding which is good in regions without conductive sediments. In regions with low and moderate conducting sediments MTS, FDEM (Frequency Domain ElectroMagnetics) and CEMP (Circular ElectroMagnetic Profiling) methods are used. Peculiarities of small scale faults mapping is considered with application to coal layer displacement in Donbass (CEMP and FDEM). A high resolution version of FDEM is proposed, which enables us possibility to define coal layer displacement's amplitude from shallower displacements of resistive layers.

SE39 Physical properties of geomaterials

02 Imaging, analysing and modelling pore structure in geomaterials

Convener: David, C.
Co-Conveners: Olgaard, D.L.; Rodriguez Rey, A.

QUANTITATIVE CHARACTERIZATION OF CARBONATE PORE SYSTEMS BY DIGITAL IMAGE ANALYSIS

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A new method of digital image analysis is capable of quantifying pore parameters in rocks over more than three orders of magnitude, from a submicron to a millimeter scale. The method is based on digital analyses of images from thin sections at variable magnifications taken under an optical microscope (OM) and under an environmental scanning electron microscope (ESEM). The method yields porosity values, pore size distributions and pore geometry characteristics that can be correlated to petrophysical and analytical parameters, such as permeability and NMR data.
The approach consists of imaging the same, uncoated thin section under the OM to quantify macroporosity, and under the ESEM to quantify microporosity. A standard image analysis program is used to detect all individual pores, and to measure pore area and pore perimeter. Based on these analyses, we calculate for each sample macroporosity, microporosity, macropore shape (by dividing the pore perimeter with a pore area value), and we establish a pore size distribution.
Tested on a set of carbonate samples, we find that macropore shape is the main control for permeability in the high-permeability samples, while the amount of intrinsic microporosity is most influential in the low-permeability samples. These results are confirmed by a sensitivity analyses for permeability using neural networks.
The range of detected pores can easily be expanded by one order of magnitudes (to approx. 1 cm), if, in addition, larger pores of whole cores or hand specimens are imaged by conventional flatbed scanners.

IS IT POSSIBLE TO CHARACTERIZE THE GEOMETRY OF A REAL POROUS MEDIUM BY A DIRECT MEASUREMENT ON A FINITE SECTION?

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At the lab-scale many properties of real porous media are strongly constrained by the micro-geometry. 2D image analysis can yield a number of parameters characterizing more or less completely the micro-geometry. Such parameters can be used to constrain generators of 3D numerical media used as input-geometries for direct 3D simulations yielding physical macroscopic properties.
A 3D natural porous medium can be viewed as the consequence of a general process including depositional and post-depositional events. In the context of the 'technique of reconstructed porous media', numerical media are produced as realizations of a random function characterized by its mean (porosity ε_β) and its autocorrelation function $\sigma(r_x,r_y)$ measured by 2D image analysis. The theoretical and practical consequences of the method are discussed. An interpretation is proposed for the nature of the geometrical information carried by $\sigma(r_x,r_y)$ and ε_β measured on a finite image. Numerical experiences are presented to illustrate the similarities and differences between simulated structures and the structure of natural media. Observed differences are shown to be due to existence of random geometrical components classified as a "structural noise" and interpreted as the consequence of the properties of $\sigma(r_x,r_y)$. This raises the need for quantifying the influence of such "structural noise" on physics in order to interpret correctly the relation between the micro-geometry and the physical properties of natural porous media.

MODELLING PHYSICAL PROPERTIES OF SANDSTONE RESERVOIRS BY BLENDING 2D IMAGE ANALYSIS DATA WITH 3D CAPILLARY PRESSURE DATA

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One quantifies the relation between the permeability and the micro-structure of natural porous media. The approach is based on image analysis: using pattern recognition algorithms and polytopic vector analysis the collection of discrete patches (PORe ELementS, "porels") exposed in a set of binary images of the geometry is characterized by a few Pore-Types (P.T.s). Achieved classification relates to the geometry of individual porels and does not relate to either 3D connectivity or spatial organization of porels. The missing structural information is obtained by applying multiple regression analysis procedures to P.T.s data combined with capillary pressure (P_c) curves. The structured nature of the obtained pore-type/throat size relation is a strong argument to interpret P.T.s as the fundamental elements of a structural hierarchy and is interpreted for granular rocks as the consequence of a general model '*the ongoing influence of a well-sorted depositional fabric coupled with the presence of clasts resistant to dissolution or recrystallization*'. Such observed relation is used to express much of the flow variability as a function of the variations in the relative abundance of the P.T.s associated to the largest throat sizes. This contribution illustrates the approach in the case of a North Sea sandstone reservoir for 29 samples representative of different stages of illite diagenesis.

THE GRAIN SCALE LOCALISATION PROCESSES: EXPERIMENTAL STUDY ON LACUSTRINE CLAYS.

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Localisation processes at the grain scale in a rock matrix are still poorly understood because they strongly depend on the material (cohesion, grain size and shape...) and deformation conditions (confining pressure. load rate...). Another difficulty is to observe *in situ* development of deformation bands. Previous works (Desrues, 1984; Tillard-Ngan *et al*, 1993) showed that, after a first phase of homogeneous distribution, localisation appears as dilatant shear deformation bands whose thickness depends on the material. Using a plane strain biaxial compression cell, stereophotogrammetry and SEM on overconsolidated lacustrine clays, the main stages of the rock matrix deformation are described. Starting from an alveolar matrix, a multistage cohesion-loss takes place: first, curved discontinuities appear around clusters and then, extend within the masses, as stress increases. Later, this cohesion-loss spreads to grain and layer scales, opening voids. Intensity of intergranular dilatancy varies throughout the matrix, possibly because of the initial compaction state of the clays. The final stage of deformation is caracterized by microfracture nucleation. First, mode I cracks are created by coalescence of the main curved discontinuities. When these fractures link, mode II fractures appear at a greater scale. Only the ultimate stages of fracturing deformation show a shear behaviour, mainly revealed by folded clay layers. The mode I stage seems to be the transition between the distributed and localized modes, inducing a rigid rock matrix behaviour.

A NEW METHOD OF SKELETON EXTRACTION AND APPLICATION FOR 3D SOIL IMAGES

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Our work aims at analyzing 3D soil images to build geometric models of soil structure and to simulate the soil hydraulic properties. Up to now, a new algorithm based on Voronoï diagrams has been developed to determine the skeleton of the 3D pore network. This provides an Euclidean distance map to the nearest solid border for any voxel in the pore space. Using this algorithm, we can obtain the pore size distribution of the 3D soil image, and can compare it with the pore size distribution within any of the 2D sections which constitute the image. Using this information and the connectivity of the pore skeleton, we can simulate fluid invasion percolation inside the pore network of the soil sample. All those methods are illustrated by simulating mercury injection in a 3D image of a cracked clay soil sample.
soil images. A new algorithm based on Voronoï diagram is developed. sample, with Euclidean distance to the border. soil image, and can compare it with the pore size distribution of each 2D slide which constitute this image. Using those informations, we can simulate the mercury invasion inside the pore network of the soil sample. All thoses methods are illustrated on a real 3D image from a soil sample of clay.

INFINITE CLUSTER IMAGING : EXPERIMENTAL ASPECTS OF WOOD'S METAL INTRUSION IN FONTAINEBLEAU SANDSTONES

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Wood's metal intrusions are performed in Fontainebleau sandstones specimens under confining pressures. Increasing capillary pressures drive the molten metal to invade the jacketed specimen from the bottom to the top, its progression is checked by means of electrical resistance measurements through the sample. The test is stopped as soon as the percolation threshold is reached (noticed by an abrupt decrease in the electrical resistance). Experiments on the determination of the surface tension and the contact angle of Wood's metal on quartz are carried on to study the feasibility of porosimetry measurements. The Wood's metal intrusion procedure provides us with filled networks ("infinite clusters") which are assumed to contain the controlling parameters of transport properties. Image analysis techniques are applied to the study of polished surfaces and used to extract the geometrical characteristics of the percolation networks. Serial crossections with very small equidistances are studied by regular optical microscopy . The final goal being 3D reconstructions in order to gain informations on the topology of the network at the percolation threshold.

2D/3D CHARACTERIZATION OF A NATURAL POROUS MEDIUM: THE CHALK

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The investigated material is a pure white chalk of Southern England (Sussex). It belongs to the Upper Cretaceous (Upper Chalk). It is made up of calcite crystallites from coccoliths microfossils (around 1 µm in size) with a loose arrangement: the porosity is about 40%. Some significant decreases of the pore volume can be detected in the material; they are evidence of tectonic strains in the matrix. Most of the pore volume is made up of micropores. The mesopores are mostly voids belonging to bigger microfossils.
The porous structure of the chalk in regard to the distribution of the calcite crystallites was studied by SEM image analysis. The bimodal distribution of meso and micropores was quantified and the total surface porosity correlated to the volume porosity by Hg porosimetry. A technique has been developed in order to consolidate the material and enable us to obtain observable surfaces without altercations. The problems arising from a wide range in observation scales are discussed.

Visualisation of Pore Structure Geometry using Confocal Scanning Laser Microscopy

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Simulation of fluid flow through sedimentary rocks can be improved by accurate determination of the 3D pore structure. While porosity can be determined by various means, critical microstructutal variables such connectivity, size distribution, tortuosity and shape can only be statistically estimated from 2D analysis. Conventional thin section imaging via scanning microscopy or optical microscopy can only analyse the surface of a sample, while serial sectioning is inherently destructive. As full understanding of fluid flow in geomaterials requires a complete description of the 3D microstructure, it is advantageous to do this non-destructively. This is possible using the relatively new technique of confocal scanning laser microscopy (CSLM). We show how 2D optical slices obtained using CSLM through a sandstone reservoir rock can be reconstructed in 3D, thus enabling the true pore geometry with depth to be visualised. Initial results coupling the CSLM data with numerical simulations of fluid flow suggest that the geometry of the pore space - in particular the 3D distribution of pore throat radii - are crucial in determining the rates and fluxes of fluid transport in porous geomedia.

INTRODUCING A PERCOLATION THRESHHOLD IN PORE-SCALE MODELLING

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An existing pore-scale model of homogenous granular media, which is very successful in predicting average flow phenomena in higher porosity regimes, is adapted to include the effect of pore throat blockages on both the hydrodynamic permeability and electric formation factor at very low porosities. Near the percolation threshold of the medium a permeable backbone is defined through which all the seepage and conduction takes place. The crux of the method lies in the modelling of the backbone tortuosity and its influence on the physics of flow and conduction. The asymptotes corresponding respectively to the percolation and the high porosity regimes are matched, rendering the results only dependent on grain size, porosity and threshhold porosity. The deterministic equations derived are applied to seepage and electric conduction through low porosity sandstones and shown to provide very good comparison with published experimental results.

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STRONG RELATIONSHIPS BETWEEN IMAGE DATA AND SANDSTONE PHYSICAL PROPERTIES

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A wide range of properties measured on three dimensional samples of sandstone are strongly correlated with aspects of porosity measured in a single 2D plane of section cutting each sample. Such properties include: fracture toughness, permeability, residual oil saturation, irreducible water saturation and NMR T1 and T2 relaxation spectra, formation factor (reciprocal normalized conductivity). Sandstones are the product of the assembly of a collection of sand grains under the forces of gravity and depositional hydrodynamics. The spatial configuration of this assembly can be defined equally well by the grains or the inter granular porosity. Intergranular porosity can be configured in only a few (perhaps only one) consistent with sedimentology and the relationships between planar porosity configurations. This assembly, predicted by Graton and Fraser (1935) consists of close packed domains separated by packing flaws. The packing flaws are circuits with long range spatial attributes that are responsible for most of the transport properties and strongly influencing fracture toughness. Two unrelated image analytical procedures can be used to study this system: porel-based erosion / dilation differencing and filtered Fourier transforms of binary images.

3D IMAGING OF POROUS MEDIA AND APPLICATION TO MICROSCALE MODELING OF TRANSPORT PROPERTIES

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We describe advances in the application of laser scanning confocal microscopy (LSCM) to image and statistically characterize the 3D microgeometry of porous geologic and engineering materials. We hope to derive new understanding of the transport properties of complex porous media by complimentary analyses of the 3D microgeometry, laboratory transport experiments, and pore-scale numerical flow simulations. We are performing systematic studies on: Fontainebleau sandstone, a pure quartz sedimentary rock with a range in porosity from 5-25%; and glass bead packs sintered to porosities of 5-35%. Back-to-back optical sections are obtained using LSCM, and image processing techniques are applied to sharpen and then segment the volumetric image data into solid and void space. The resulting binary data are processed to extract statistical descriptions of first-order geometric parameters such as porosity and specific surface area using n-point probability functions. Higher-order parameters that seek to capture spatially distributed geometric attributes of the pore structure are obtained using a medial axis analysis as formulated by Lindquist (JGR, 1995). In parallel, we are performing laboratory measurements of permeability as a function of hydrostatic stress. Finally, we discuss the use of LSCM to generate geometric models that are used in 3D numerical simulations of non-reactive transport using the Lattice Boltzmann Method.

IMAGING AND ANALYZING ROCK POROSITY BY AUTORADIOGRAPHY AND HG-POROSIMETRY/COMPUTERTOMOGRAPHY

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The development of two methods for the assessment of the ability of different rocks to retard radionuclides migrating in groundwater by diffusion and sorption is reported. The potential for application of the methods, however, is wider, e.g. mechanical rock properties have not yet been considered. The retardation ability is dependent on size and structure of the accessible pore space and internal surfaces. Impregnation with labelled PMMA and autoradiography allows the investigation of the pattern of the spatial porosity distribution and quantitative measurement of mineral-specific, lo-cal porosities, as well as an assessment of hydraulic and diffusive transport proper-ties. Quantitative information on surface areas within certain pore size ranges can be achieved by combination of mercury intrusion porosimetry with X-ray absorption computertomography. In rocks with a pronounced intrusion-extrusion hysteresis 3D-images of the pore network between certain limits of apertures can be obtained and mineral-specific internal surface areas can be estimated. The resolution is about 10-30 µm (autoradiography) and 50 µm (tomography). In very narrow pore systems method-specific dependencies of the results on the probe molecule have been found for methods applied for the pore space characterization. New applications are under development, namely, modelling of diffusion in heterogeneous matrices, texture analysis, characterization of excavation disturbed zones and the study of fracture formation under stress or stress release effects.

PORE FABRICS OF CERAMIC MODELS INVESTIGATED BY MAGNETIC ANISOTROPY

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Ceramics (roofing tiles) with relatively high porosity (above 30 %) was used as model to investigate the pore fabric formed during ductile deformation. The pore fabric was investigated through measuring magnetic anisotropy of the specimens having their pores saturated by a ferromagnetic fluid. The ductile deformation of the ceramics was investigated through measurement of magnetic anisotropy of dry specimens. The character and symmetry of the pore fabric are compatible with those of the deformations forming the fabric of the ceramics.

ON MODIFICATION OF SPATIAL POSITION OF ELASTIC SYMMETRY ELEMENTS UNDER PRESSURE.

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Spatial position of elastic symmetry elements of rocks does not always coincide with orientation of textural-structural elements. Elastic symmetry of rocks is a result of combined influence of elastic symmetry of rock-forming mineral grains and microcracks on the grain boundaries. Orientation of grains and microfractures depends on the influence of paleo and modern stresses on the rock. The influence of stress on spatial orientation of elastic symmetry elements of rocks has been investigated by means of acoustopolariscopy method. Samples were sounded along the direction, normal to the load application direction. Maximum pressure was 90 MPa, a step of loading – 15 MPa. It was established that the majority of rocks change the orientation of elastic symmetry elements by 5-15°, in some cases (granodiorite) – the angle of rotation reaches 91°. The degree of reorientation of elastic symmetry elements in strong crystal rocks resulting from uniaxial loading mainly depends on the degree of rocks jointing as well as on homogeneity of their structure and mineral composition.

3-D DEFORMATION ANALYSIS BASED ON HIGH RESOLUTION X-RAY TOMOGRAPHS

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The objective of this research is to provide fundamental understanding of deformation and fluid flow in rocks at the grain and pore scale, under conditions of static and dynamic loading. Our approach is to utilize high resolution 3-dimensional images of rock microstructures in conjunction with high performance numerical techniques to simulate of the behavior of the rock-fluid system on the scale of microns to millimeters. In particular we utilize X-ray tomographic microscopy (XTM) to provide high resolution 3-dimensional images of rock microstructure, including the mechanical frame work of grains (matrix) in addition to the pore space. We have developed a new finite-element numerical model to simulate the static and dynamic mechanical behavior of rock at the pore scale, which allows us to fully resolve all the details of an XTM image. We are starting to use the model to predict where cracking and/or fracture can be expected in the imaged samples. After validating the model we will use it to investigate connections between macroscopic stress-strain behavior and the patterns and energetics of localized fracture.

INVESTIGATING THREE DIMENSIONAL GEOMETRY OF POROUS MEDIA FROM HIGH RESOLUTION IMAGES

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The leading X-ray computed microtomographic imaging facilities can now provide 1024^3 voxel images of rock and other porous media samples at a voxel resolution of about 5 microns. Scanning laser confocal microscopy measurements of rock can provide images at sub-micron resolution. though with limitations involving depth and the resolution of isolated voids. These data sets are extremely rich in information, but are overwhelming in size; one 1024^3 data set corresponds to a gigabyte of character data.
We have developed a computational package called 3DMA to use as a tool to provide analysis of the geometry of the pore and grain phases of digitized three dimensional images. Current analyses for each phase include determination of volume fraction, specific surface area, 2-point spatial covariance, disconnected volume distribution, the medial axis (1D skeleton). path length and tortuosity distribution, coordination number. throat size and nodal pore volume distributions. We have applied this analysis to a variety of porous media images including rocks (sandstones, basalts, carbonates). glass micro-bead packs, cellulose fiber networks, and biological images (neurons) and two-fluid mixtures. Medial axis analysis is a central component of the package. It provides a one dimensional 'skeleton' enabling efficient searching and geometrical characterization as well as a 'graph' for the application of graph theoretic network tools.

FRACTURE NETWORK VERSUS SINGLE FRACTURES: MEASUREMENT OF FRACTURE GEOMETRY WITH X-RAY TOMOGRAPHY

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Several long-standing questions concerning fluid transport in fractured rock involve the geometrical properties of the connected void space within a fracture network. We present experimental results that compare the geometrical properties of a fracture network to those of the individual fractures in the network. To image and quantify the aperture distribution of natural fracture networks in coal, a Wood's metal injection method is combined with X-ray computerized tomography and image analysis. We find that the aperture distribution of the networks are spatially anisotropic and dependent on the number and geometry of the individual fractures. Void area in the individual fractures ranged between 38% - 49%. A three-dimensional auto-correlation analysis on the fracture network found that the apertures were correlated over distances of 6 mm to 30 mm and the correlation slope differed between the two-orthogonal directions. Our results suggest that three-dimensional extrapolations from two-dimensional cross-sections may not lead to faithful representations of fracture networks for distances that exceed the correlation length.

LASER CONFOCAL MICROSCOPY STUDY OF THE 3-D CRACK NETWORK OF MECHANICALLY AND THERMALLY DEFORMED GRANITE SAMPLES.

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Laser confocal microscopy (LCM) was used to characterise 3D crack networks in La Peyratte granite samples in which cracking has been artificially induced. Our goal was to recognise typical crack patterns associated with different cracking mechanisms. We have taken advantage of the ability of LCM to image thin slices within the rock sample in two different ways : first there are no overprojection problems for stereological studies, and second, one can obtain series of images at different depths from which the 3-D crack network can be reconstructed.

Thermal cracks were induced by heating selected samples at different temperatures. Other samples were deformed under triaxial conditions at maximum deviatoric stresses close to but lower than the rock failure stress, to generate stress-induced cracking. A thorough microstructural analysis was conducted on polished sections obtained from the cracked samples impregnated with a fluorescent epoxy. Stereological procedures were applied in order to estimate crack parameters. In addition some 3-D reconstructions were made on selected areas. Both our 2D and 3D analyses showed a striking difference between thermally cracked and mechanically cracked samples, which is the presence of a strong anisotropy of crack orientation in the latter not observed in the former.

2D AND 3D GEOMETRY OF SOILS : PORE SIZE DISTRIBUTION AND PERCOLATION PATHS

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Can one characterize electric and hydraulic phenomena inside a soil by 2D image analysis ? In order to respond to this question, the goal of our work consists in comparing the 2D and 3D structures of soils.
Two kinds of geometry are studied : (i) the crack network of a heterogeneous clay soil reconstructed by serial sectioning and (ii) the pore set of a homogeneous porous medium modelled by random packing of unequal deformed spheres.
In the both cases, two morphological and topological caracteristics are observed by two- and three-dimensional image analysis :
(j) the pore size distribution obtained by granulometry and (jj) the percolation threshold associated to the width of the fluid flow path narrowings.
Two main results can be deduced :
(k) For the clay soil, the 2D and 3D pore size distributions are similar even when the percolation threshold of the fluid flow paths is highly under-estimated in 2D.
(kk) The morphology and the connectivity of the 3D porous medium may be characterized by the analysis of some two-dimensional cross-sections.

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ESTIMATION OF PORE GEOMETRY PARAMETERS IN ROCKS FROM SINGLE SECTIONS BY STEREOLOGY

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Stereology provides efficient procedures for quantifying rock-forming components. as pore geometry of rocks. an important data on many applications; its influence on transport properties, geomechanical behaviour, etc. has been clearly recognized. In fact porosity is a key data in Rock Engineering, Stone Conservation, Rock Store, ... Classically, pore volume and surface area are the most used parameters regarding porosity, as well as the mean pore size (number-weighted); the latter requires serial sections to be estimated by stereology. The volume-weighted mean size is a less common parameter that can be more useful in case of very skewed pore size distribution, that is, when a few very large pores coexist with many small ones. A practical advantage is that it can be estimated on single sections. As a methodological example, all the mentioned parameters are here estimated using a very simple. fast and inexpensive stereological procedure on scanning electron microscopy images. The oolitic limestone used as a building stone in the Cathedral of Sevilla (Spain) and the Bangombe sandstone, from the Oklo (Gabon) natural analogue site, are the two examples included: therefore, two important fields as Stone Conservation and Disposal of Radioactive Wastes are here represented.

MICROSCALE FLOW MODELING IN GEOLOGIC MATERIALS

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Innovations in 3D imaging techniques, numerical models of fluid transport, and computational architectures now allow simulations of flow in porous media to be performed at the microscale. High resolution reconstructions of geologic and engineering materials using LSCM are large enough to minimise sampling artifacts, and also provide access to the representative scale lengths at which porous media flow needs to be characterised. However, typical 3D data sets are extremely large, and to utilize this information effectively there are significant issues regarding the tractable computation of transport phenomena at the pore scale. The principal problem lies in the complexity of the geometry and the retention of this structure in subsequent numerical analyses. Lattice Boltzmann Methods (LBM) have arisen as the most attractive approach to simulate transport processes in complex geometric domains due to the unique ability to simply and efficiently treat the multitude of discrete boundary conditions. LBM are also numerically explicit as formulated, thereby permitting the effective application of distributed computing methods to the problem. Here we describe the results of single phase flow simulations in 3D data sets obtained from Fountainebleau sandstone core samples using LSCM. Simulations are performed using both a purpose-built distributed processor system and a massively parallel processer (MPP) platform. Permeability measurements predicted numerically are compared with those from laboratory flow experiments.

ALTERATION INFLUENCE ON MICROPOROSITY CONNECTIVITY OF CHARROUX-CIVRAY TONALITE.

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Potential nuclear wastes storage in rocks raises the problem of long term safety of the ultimate repository barrier. Pervasive and vein alterations modify strongly the microporosity of rocks and so its hydro-mechanical capabilities. In order to assess transport properties evolution versus alteration, we have studied few graduate clay-carbonate facies in comparison with an unaltered one. The aim of this work is so, to locate probable and potential fluid pathways and, to understand how they could evolved or be developed in time. Tools used are 2D-image analysis and physical measurements. 2D-parameters are obtained, at core scale, concerning morphological features and spatial distribution of primary mineral phases. A specific staining method was adapted, for core sections, based on K-ferrycianide and HF attack, to allow an accurate and useful mineral segmentation. These techniques prove to be successful with the different utilised facies. At grain scale, S.E.M. statistical analysis permits to locate and quantify microporosity. 3D-parameters are obtained by Hg-porosimetry and by a specific water permeability experiment under low-pressure conditions. This investigation provides, a good understanding of granular rock features versus alteration. Appropriate parameters are deduced and can be used with percolation models. Finally, tools and techniques developed contribute to the approach of real 3D characterisation of rocks.

SIMULATION OF 2D GRANITE CRACK SYSTEMS FROM IMAGE ANALYSIS AND STEREOLOGICAL DATA.

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Transport properties of two unaltered polyphasic igneous rocks (granite and tonalite) are studied from image analysis and stereological results. Microcracks are considered to represent the most important small scale fluid vector of the rock. On the studied samples, we consider that they are probably due to rock decompression. The proposed model of porosity is geometrically constrained by spatial distribution of mineral grains, and is obtained from two scales. First, at the scale of grain mosaic, image analysis provides a 2D representation of primary mineral species distribution, which defines grain-boundaries network. Secondly, at the scale of the pores, S.E.M. stereological counting provides two main features of inter and intra-granular cracks : opening probability and aperture distribution. These data allow to reconstruct, via Monte-Carlo simulations, models of 2D cracks distributions, according to the opening probability of each crack types. 2D transport parameters are then determined from these simulations : tortuosity, connected and efficient porosity, and size of the neck zones. Validity of this model mainly depends on image analysis operations : intragranular reconstruction represents the more hypothetical one. Although these networks represent obviously more realistic model than regular networks, percolation effect should be compared for these two kinds of model.

MICRO AND MACROFRACTURES PLANES ROUGHNESS. EVIDENCES OF HIGH CHENALIZATIONS OF FLUIDS AND CONSEQUENCES ON FLUID-ROCK INTERACTIONS.

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Rough fractures are characterized by a channelling of fluids flows inducing high heterogeneity of the fracture hydraulic and transport properties. This anisotropy is controlled by the presence of contact points (in situ normal loads) and by the distribution of apertures (residual voids). The fracture roughness and consequently its tortuosity imply reduced permeabilities and more complex fluid-rock exchange surfaces, compared to the parallel and smooth plates models. The purpose of this work is therefore to characterize these physical parameters using finite differences modelizations. A hydromechanical model of fluid flow in rough fractures has been performed and two scales of fracturation were observed. The morphology of fracture planes (macroscopic scale) was quantified by a mechanical numerization of profiles. Microcracks were studied on thin sections with image analysis. The quantification of roughness, tortuosity, the statistical distribution of apertures and the relations between surface properties and mineralogy or fracture orientations have been undertaken. These results from the studies of natural fractures at micro and macroscopic scales are finally compared and integrated in the model. Then, hydromechanical and chemical behaviour of these fractures submitted to fluid percolation can be described.

MICROSTRUCTURE AND TRANSPORT IN RESERVOIR ROCKS

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The defining characteristic of porous media is that they are comprised of two percolating interconnected channels, the solid and pore networks. Transport processes of interest typically involve the flow of electrical current, viscous fluids or fine grained particles through the pore network. A closely related phenomena, nuclear magnetic resonance (NMR), is controlled by diffusion in the pore network. We will show that the physical properties of rocks can be understood by combining three dimensional model porous media and direct measurement of the pore structure by synchrotron X-ray microtomography. Of particular interest are geological systems that are uniform when viewed above a cutoff length scale but are heterogeneous when viewed below that length scale. This is often the case in shaly sands and carbonate rocks with combined inter-granular and micro-porosity. Here we are especially concerned with the relationship between NMR measurements and the underlying pore structure. We will show that a combination of numerical and analytic models can be used to put this relationship on a sound basis. Here the central issue is to describe properly diffusion between the micro and macropores.

IMAGE ANALYSIS, AND ESTIMATION OF POROSITY AND PERMEABILITY OF ARNAGER GREENSAND, UPPER CRETACEOUS, DENMARK

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Arnager Greensand consist of unconsolidated, poorly sorted fine grained, glauconitic quartz sand, often silty or clayey, with a few horizons of cemented coarse grained sand. Samples from the upper part of the Arnager Greensand were used for this study. Backscattered SEM images from polished thin-sections were acquired for the image analysis with the software PIPPIN. Estimations of porosity, clay and grain content were measured from the image, due to the difference in grey levels caused by density differences. No attempt was made to separate between the different mineral grains, due to their similar density. The images were simplified into two phases: pores and particles. A filter was applied to the image to calculate the specific surface of the grains. The Kozeny-Carman Equation was used to calculate the permeability. The most significant errors incurred in the permeability calculation are believed to be caused by uncertainties in the specific surface, due to the high clay content.

MULTISCALE CHARACTERIZATION OF THE GEOMETRICAL AND TRANSPORT PROPERTIES OF A FONTAINEBLEAU SANDSTONE FROM MICROTOMOGRAPHIC IMAGING

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A piece of low-porosity (7%) Fontainebleau sandstone was scanned at ESRF and a high-resolution (6.3 μm) three-dimensional binary image was reconstructed by synchrotron computed microtomography (CMT). A $(512)^3$ voxels domain was cut from the center of the rock piece and its geometrical and transport properties were thoroughly numerically investigated. Emphasis was put on the characterization of the spatial heterogeneities and on the scale dependency of local averages. Thanks to the size and resolution of the data set, significant statistics could be obtained for averaging volumes varying from 16^3 voxels (comparable to the typical grain size) to 256^3 voxels. Geometrical characterization included porosity, correlations and variogram measurements and a multifractal analysis. Then, the percolation was tested and the conductivity (inverse of the formation factor) was computed along three orthogonal axes for all the cubic subdomains. The spatial and statistical organizations of these quantities was characterized. Among other results, the local porosities and conductivities are shown to obey a lognormal distribution, and their standard deviations to decay according to a power law of the sampling domain size.

FRACTURE SOURCE MAPPING IN DEFORMED GRANITE BY ADVANCED ACOUSTIC EMISSION AND X-RAY TOMOGRAPHY

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Asymmetric uniaxial compression tests were performed on granite cores (diameter 50 mm, length 100 mm) from the Erzgebirge, Germany. The loading scenario, where part (20%) of the core top surface remains unloaded, induces a shear rupture, which propagates from top to bottom of the sample. The propagation and growth of the fracture process zone is mapped in three dimensions by locations of microcrack induced acoustic emissions. The brittle failure of granite is stabilized by controlling axial stress to maintain a constant rate of acoustic signals. First pulse polarity analysis of acoustic emission wavelets shows that in asymmetric compression of granite shear type events dominate (70%). The positions of shear microfractures with strong amplitudes align with the future macroshear plane. Fault plane solutions of single shear events show a large variation in the orientation of nodal planes with respect to the orientation of macroshear plane determined from X-ray tomography. Composite fault plane solutions coincide with the overall orientation of the macroshear plane. X-ray tomograms from asymmetrically tested cores indicate en-echelon crack orientation related to the fracture nucleation.

SE39 Physical properties of geomaterials

03 The effect of rock micro-structure and fluids on rock physical properties

Convener: Glover, P.W.
Co-Convener: Main, I.

PORE STRUCTURE AND TRANSPORT IN A PURE SANDSTONE - DETERMINATION OF RELEVANT PROPERTIES

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The pore structures of 22 samples of the Lochaline Sst Formation were investigated employing microscopy combined with SEM-image analysis, mercury intrusion porosimetry, helium porosimetry and electrical conductivity measurements.
Transport properties were studied measuring gas-permeabilities (Klinkenberg corrected) at 400psi confining pressure and electrical conductivities at 1kHz. The apparently complete "pore fraction distribution" relevant for transport was determined using a combination of data from SEM-image analysis and mercury intrusion which enables to measure pores from 0.01 micrometer up to several millimetres in diameter.
On this basis "effective" pore structure parameters like hydraulic pore radius (Konzeny-Carman Eq.) and pore radius at the capillary threshold pressure (Pittman -Eq.) were derived and used for direct calculations of permeabilities.
The well known relationship $F=\emptyset^{-m}$ fits well most of the data. The perm-porosity cross plot reveals a reasonable power-law relation which could even be improved by plotting only the euclidical porosity which is relevant for transport processes.
As a result, pore structure and it's influence on transport properties can only be satisfactorily described for each individual sample by integration of parameters derived from several different samples.

FLUID PATHWAYS IN CRYSTALLINE ROCK

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Fracture systems and fluid pathways are essential objectives to understand the dynamical processes of the upper crust. The connectivity of fractures and their contribution to the fluid transport are generally not scale invariant, i.e. there is no representative elementary volume in crystalline rock. Key parameters to characterize fractures and to determine hydraulic permeability and porosity are the geometrical fracture parameters and their statistical distribution functions on different scales. Physical relations between measured and derived parameters as well as data from structural borehole measurements were used for network modelling to estimate the hydraulic flow. This yielded a quantification of the scale dependent relation between porosity and permeability. The essential part of porosity is located in microfractures, wheras the contribution to the hydraulic transport is of subordinate nature; on the other side, only a small amount of fracture porosity is needed for the macroscopic fluid transport through fracture networks.

COUPLED EVOLUTIONS OF MICRO-GEOMETRY AND TRANSPORT PROPERTIES: A NUMERICAL STUDY FOR SIMPLE POROUS MEDIA

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The evolution during mineral diagenesis of porous rocks physical properties is a very complex problem. When properties like effective diffusivity, formation factor or permeability are considered interest can be focussed on the coupled evolutions of micro-geometry and transport properties.
This approach is theoretically justified using the volume averaging method: This now classical method yields to differential problems at the microscopic scale. Their resolution permits the computation of the macroscopic transport properties. For the properties listed above, the results are completely controlled by the microscopic geometry.
For well-sorted granular porous media, random closed packs of spheres having realistic porosity are good first approximations of initial micro-geometry. After a short presentation of the program developed to satisfy this requirement, the principles of the different methods used to modify the micro-geometry are exposed.
The differences observed between the purely geometrical evolution and the geochemically governed evolutions suggested that both the history and the depositional conditions influence the properties of natural porous media.

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ELECTRICAL AND HYDRAULIC PROPERTIES OF PYROCLASTIC ROCKS AND THEIR RELATIONS TO MICROSTRUCTURE.

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Important electrical resistivity variations have been observed before volcanic eruptions. In order to interprete these variations data on electrical properties of volcanic rocks under laboratory controlled conditions are necessary. In this work, we have measured porosity, permeability and electrical conductivity in 48 samples coming from different evolutionary stages of Mount Pelee volcano (Martinique, Lesser Antilles). The samples are representative of different lithologies of this volcano (dense or porous blocks, pumice, scorias and lavas). The pore space geometry has been characterized by mercury injection, observation of thin sections and B.E.T. Porosity of samples ranges from 0.03 to 0.60 and permeability cover more than six orders of magnitude ($7\ 10^{-17}$ to $3.4\ 10^{-11}\ m^2$). Formation factor varies from 9 to 625 and surface conductivity from 0.15 to 24 mSm^{-1} and being well correlated with the C.E.C. Unusual values of cementation exponent (m=5) is obtained in pumices, indicating a total decoupling between total porosity and the part of the porosity used by the electrical current. Grouping the data for all the samples, it appears that the formation factor is well correlated with the permeability, even though permeability displays a weak correlation with porosity.

TRANSPORT PROPERTIES OF SEDIMENTARY AND VOLCANIC ROCKS

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To compare the transport properties of volcanic and those of sedimentary rocks, we focus to some aspects, such as the influence of the length scale heterogeneities and properties when two fluids saturate the rock. We have measured the permeability in monophasic and diphasic conditions and analyzed the displacement of two miscible fluids, in order to provide information on the preferential pathways for fluid flow. All those experiments are made on large sized samples (3 litres of rock). The rock microstructure has been studied using mercury injection and microscopical observations of thin-section.
Results have shown that :
- There are few differences between sedimentary and volcanic rocks. Volcanic rock have high relative water permeability and high tortuosity, this reflecting the effect of multimodal pore throat size distribution.
- Small percolation threshold denotes preferential pathways for fluid flow. It is associated with high tortuosity and with crack porosity type.

The results obtained have been used to test different models. The network model seems to be the most appropriate in accounting for the hydraulic behaviour of sedimentary and volcanic rocks in terms of microstructural parameters.

THE INFLUENCE OF MICROHETEROGENEOUS INCLUSIONS ON PHYSYCAL PROPERTIES OF ROCKS (A STUDY BY USING SYNTHETIC PHYSICAL MODELS)

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High precision of the experiments has been provided by methods of standardizing, by applying of spectral and polarization analysis. The heart of the experiment was a special technological background including: a design of materials with low melting-point micro-inclusions which let change reversibly the phase constitution of pore-filler; a design of synthetic materials with free porosity, permitting to change reversibly the substantial contents of a pore-filler; a development of technologies for producing controlled crack systems with a changeable pore-filler. Some new effects have been revealed. It has been discovered that the total surface and the total volume of microheterogeneities influence on the velocity and attenuative properties of the material, whereas sizes of the constituent inclusions have no serious significance. An essential anisotropy of the media containing the directed crack-like heterogeneities with prevailing opening directions has been revealed. The influence of cracks filled with gas and liquid therewith occurs to be essentially different for shear and compressional waves. There is a reason to suppose that, in symmetry properties, these media are transversely isotropic, with five parameters to describe anelastic exhibitions of a medium via a wave-front position in wave propagation as well as five elasticity moduli are needed to describe velocity properties.

CRITICAL SIZE OF CRYSTALLITES IN ELECTRICAL CONDUCTIVITY OF GRAPHITIC ROCKS

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The electrical conductivity of graphitic rocks (black shales) is an actual and discussed problem, given the spreading of the conductivity values obtained both in situ and in laboratory. We studied the electrical behaviour of black shale samples coming from boreholes at simulated physical conditions (Hydrostatic pressure up to 39 MPa; Internal fluid pressure up to 36 MPa; temperature up to 230 °C) and analysed the petrographic structure, the mineralogical and chemical composition of the samples by using optical and electronic microscopes (TEM, SEM) and chemical analysis. The main research result is the role of no-graphitic crystallites in activating the electronic conduction mechanism of the graphite in the whole rock sample. In fact the requested 'continuity' of the graphitic net can be created also in presence of few percent of graphite, if the rock crystallites have dimensions under a critical size and the phyllosilicates can joint to the graphite creating a global layered structure, thanks to the common 2D crystalline structure of these minerals. A physical interpretative model of the black shale electrical behaviour is described.

SYNTHETIC ROUGH FRACTURES IN ROCKS FOR FLOW MODELLING

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Natural fractures serve a very important function in the transport of fluid, electrical charge and heat through rocks. Numerically synthesised fractures can aid the study of the physical processes connected with fractures. We present methods for producing synthetic rough surfaces whose geometric properties are tuned to mimic natural fracture surfaces in rocks in order to be able to create synthetic fractures that are statistically identical to those found in rocks. The method allows the surfaces of a fracture to be matched at long wavelengths, and be unmatched at short wavelengths. In between the degree of matching varying smoothly, as it does for real fractures. We have compared numerically synthetic fractures created using the new method with fractures created using an existing technique that uses a mismatch wavelength as a sudden discontinuity between matched and unmatched behaviour, as well as data from fractures in real rocks. This comparison has shown that the new technique provides much more realistic numerically synthesised fractures than previous methods.

EQUILIBRIUM FLUCTUATIONS AND GEOMETRY-CHANGE TRANSITIONS OF SOLID INTERFACES.

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Investigation of temperature dependence of solid interface atomic-scale geometry was performed using Monte Carlo simulation for 2D lattice model. Equilibrium fluctuations of interface were studied by means of correlation function and morphological analysis methods. Depending on the conditions solid interface takes crystalline, quasicrystalline or amorphous structure.
Sharp increases of interface fluctuation amplitude at certain temperatures was found to be related to geometry-change phase transitions. Geometry-change phase transitions leads to change in equilibrium geometry, physical and chemical properties of phases in nanosized state.

FLUID FLOW IN SYNTHETIC ROUGH FRACTURES AND APPLICATION TO A FIELD SCALE FRACTURE

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Fracture profiles from a geothermal HDR test site in N. Japan have been analysed to characterise their geometrical properties. These properties have been used to create a population of synthetic fractures tuned to imitate all the geometric /statistical properties of the natural fracture. Such fractures have been used in three types of modelling; (i) elastic normal closure relating fracture aperture to normal load, (ii) Hagen-Poiseuille calculations of fluid transmissivity as a function of normal load, fluid pressure, and temperature, and (iii) Reynolds equation flow modelling. The modelled closure of synthetic fractures provided realistic relationships between normal load, fracture fluid pressure and aperture. When these relationships were used to calculate fluid transmissivity in the fracture with a Hagen-Poiseuille approach, the results showed the same functional dependency with fluid pressure as transmissivity from field tests, but were overestimated by a factor of about 2. Reynolds equation flow modelling was carried out to ascertain the extent to which the Hagen-Poiseuille law was overestimating the transmissivity due to the rough fracture surfaces. When the calculations were corrected for this effect, the calculated fluid transmissivity was a much better match to the field data.

ON INFLUENCE OF MICROSTRUCTURE OF ROCKS ON SPATIAL POSITION OF ELASTIC SYMMETRY ELEMENTS.

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Comparison of microstructural investigations in thin sections and results of acoustopolariscopic studies of basic and acidic rocks have been carried out. Acoustopolariscopic method reveals orientations of elastic symmetry elements corresponding to the directions of polarized s-waves with maximal speeds and minimal losses of their amplitudes. Comparison of the results of investigations in thin section of plagiolertholite, melano-gabbro-norite, pyroxene-plagioclase olivinite, olivine gabbro-norite and olivinite shows that elastic symmetry elements coincide with zones of alteration, affecting grains of olivine. These alterations result in systems of microfractures filled in by magnetite. Elastic symmetry elements in samples of biotite plagiogranite coincide with elongation of biotite grains.

P- and S-wave velocities and attenuation in relevant crustal rocks at PT conditions and the role of intercrystalline fluids

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Most physical rock properties at conditions of great depth are affected by a number of lithological and physical parameters (PT-conditions). The lithological parameters include the properties of the rock matrix and of the pore space (cracks, intercrystalline fluids).
We will present experimental velocity and attenuation (resp. Q) data for relevant dry and wet crustal rocks and discuss their pressure and temperature dependence. Measurements were done in a cubic anvil pressure apparatus and in a oil chamber using the pulse transmission technique.
It will be shown that there is a close pressure and temperature sensitivity of P- and S-wave velocities and the respective Q-values in dry rocks due to the closure and opening of grain boundary cracks, respectively. Introduction of an intercrystalline fluid by saturation of the rock or by thermally-induced release of chemically-bound water affects velocities and Q-values quite differently. The experiments reveal that combined measurements of Vp and Vs, using the Vp/Vs ratio, may give evidence for fluids on grain boundaries.
The experimental findings, as reflected by the variations in the petrophysical parameters, are considered to be of importance for the interpretation of natural dehydration and hydration processes in the crust caused by prograde and retrograde metamorphism, respectively.

COMPLETE PORE SIZE DISTRIBUTIONS OF ROCKS CONTROLLING COMPLEX ELECTRICAL AND TRANSPORT PROPERTIES

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Pore size distributions of various confined rocks were measured with N_2-adsorption. mercury injection. and image analysis methods. A general power law pattern of the distribution was found which accords to the fractal pigeon hole model of Pape. Riepe and Schopper (Log Analyst.1982). The power law pattern means a constant ratio of adjacent radius classes when their spacing is logarithmical.
Only few parameters are needed for the mathematical description of the distributions. yielding simple functional relationships between sorption. diffusion. and advection parameters. Deviations from these relationships are easily recognizable as deviations from the model pore size distribution.
These fractal boundary conditions also cause a Cole-Cole frequency behaviour of complex conductivity in the hertz to megahertz range. This is due to a internal surface polarization mechanism. which may be interpreted as a power law distribution of relaxation time constants. A possible application of these results is the calculation of internal surface area from the frequency dependence. a estimation of water saturation. salinity. or even permeability. with the aid of the complex conductivity or dielectrical permittivity.

MECHANICAL BEHAVIOUR OF MIOCENE SOFT ROCKS AND THEIR MICRO-STUCTURE

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The subsoil of Lisbon is mainly composed of Miocene terranes that include, from the geotechnical point of view, over-consolidated clayey and sandy soils (hard soils) and soft carbonate rocks. In order to allow the evaluation of the seismic behaviour of these terranes, a geotechnical characterisation of materials was made, that included the study of strength, physical properties and micro-structure. Miocene rocks form lenticular beds and include sandstones and clastic limestones, with unexpected very low Point Load strength. This behaviour is related with the micro-structure of the rock, mainly crack and pore structure, nature and extent of cementing bonds, and composition and shape of the clastic component. In order to understand this behaviour, the rock micro-structure was studied in detail, along with the measurement of ultrasonic properties and of the tensile strength of the materials. The tensile strength measurements were made using tension tests similar to the Hoop Test. The specimens were cut with the shape of parallelepiped, with a cilindrical hole in the center of the larger face, where the tension load is applied paralell to the largest dimension. The rock slices for micro-structure study were cut in various directions of each specimen.

MICROPLASTICITY AND PHYSICAL NONLINEARITY OF GEOMATERIALS

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In experiments on the samples of sedimentary rocks (sandstones. marls. dolomites, with depths 2 - 3km). microplastic property are found out. Microplasticity of geomaterials is displayed in step-wise growth of irreversible residual deformations while loading (at the level of common deformation $\varepsilon = 10^{-7} - 10^{-3}$). Microplasticity grows non-linearly as the porosity increases. Due to microplastic inelasticity, the deformation-process diagrams $\sigma(\varepsilon)$ are of the form of non-closed hysteresis loops. In the mechanical rocks model microplastic modules M_μ is introduced. Curves of elasticity modules $E(\varepsilon)$ have the identical loops. Static and dynamic elasticity modules differences is caused by visco-elasticity and microplasticity. The absorption in the microplastic media depends on wave amplitudes. Acoustic emission in the microplastic media is observed. Inelastic-property differrences in three mutually-perpendicular directions, named as microplastic anisotropy. are found out. Microplastic anisotropy involves not only anisotropy of seismic velocities but also the dependence of absorption properties on wave-propagation direction.

EFFECTS OF SURFACE CONDUCTIVITY ON FORMATION FACTOR: A NUMERICAL STUDY FOR SIMPLE POROUS MEDIA

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Because they are easy to measure in situ as well as in the laboratory, electrical properties are broadly used to characterise natural porous media. When some minerals, like chlorite, are present, electrical phenomena occur near the fluid/solid interface inducing a surface conductivity that might influence the bulk properties and greatly distort their interpretation.
Using the now classical volume averaging method it is rather easy to formulate a differential problem at the microscopic scale which solution permits the computation of the macroscopic physical properties. After a short presentation of the theory in the case of electrical conduction with surface conductivity, the principles and the main characteristics of the numerical method are presented.
Results are proposed for simple porous media (random close packs of spheres) having realistic porosity (about 35%) and for sandstone like porous media reconstructed using real geometrical data.
Special attention will be paid to the important role played by the spatial distribution of the different minerals composing the solid phase.

SEISMIC DYNAMIC INVERSION USING COMPRESSIONAL AND CONVERTED WAVES

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Different ways for estimation of three independent elastic parameters (compression wave velocity Vp, shear wave velocity Vs and density ro) has been studied. They are based on a polynomial approximation for dependence between frequency characteristics of a layer or a thin-layered zone reflection and an incident angle. Linearized problem has been considered on the assumption that the elastic property changes at the boundaries are small. Stability and accuracy of the parameters estimating for 1D model have been analyzed. As the result, it has been shown that the most accurate solution can be obtained in the case of square approximation of reflection characteristics for the middle offset part. In the case of a random noise there are biased estimators for the first polynomial coefficients and high dispersions for the second coefficients. This resulted in the solution instability for small offsets, hence an iteration R-algorithm has been suggested. This algorithm permits to obtain stable non-biased estimators for the elastic parameters with a high noise level. Conditions providing maximum convergence speed have been determined. The ways suggested broadens the capabilities of seismic methods to determine rock petrophysical characteristics: Poisson's ratio, Young's Modulus and to compute the medium stress tensor.

THE INFLUENCE OF FLUORITE AND BARITE CEMENTATION ON POROSITY AND PERMEABILITY IN RESERVOIR AND RESERVOIR ANALOGUE SANDSTONES.

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Outcrop (sandstone) plugs from the Rotliegende Hopeman Sandstone (from the Inner Moray Firth Basin, Scotland) and cores from the Vanguard Field, Southern North Sea (Rotliegende) have been analysed for the relationship between fluorite and barite cementation and petrophysical properties. The cements are compositionally zoned and their distribution is controlled by fractures. There appears to be a link between zonation of mineral cements in veins and the structural evolution of both the reservoir and outcrop examples. This study of fracture cements has important implications for the evolution of porosity and permeability in these rocks. Permeability and helium porosity have been measured on core plugs, and mercury injection porosity on plug offcuts. Permeability variation between fracture cements have been measured using a minipermeameter on outcrop and core samples. Mineral cements are preferentially precipitated in layers with high depositional porosity and permeability but are less effective in modifying rocks with originally moderate porosity/permeability. Hence the introduction of these cements via fractures can severely modify flow characteristics through the formation.

THE EFFECT OF WATER-SATURATION ON THERMAL CONDUCTIVITY

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Use of the needle probe technique to measure the thermal conductivity of water-saturated rocks and considering experiments under conditions of elevated temperature and pressure provides sufficient information to investigate various aspects of the effect of water-saturation on thermal conduction. These aspects include (1) theoretical models of the two-phase (matrix-fluid) system, which are verified using measurements from intact rocks and fragments, and known porosity values, (2) porosity and its structure, which are investigated by comparing thermal conductivity measurements from dry and water-saturated rocks, (3) compaction of the shallow sea floor sediments, which can be estimated considering variations of thermal conductivity with depth, (4) thermal cracking, which alters the bulk rock properties during measurements high-temperature and is minimized by simply keeping the samples saturated. Thermal conductivity measurements are a proxy method to provide first-order information about mineral composition, matrix texture, porosity, pore-space anisotropy, and sedimentation processes. This information is helpful for planing detailed studies with more sophisticated and time-consuming methods. The decrease of thermal conductivity with increasing temperature may be overestimated if based on measurements from dry samples.

SPONTANEOUS POLARIZATION OF WATER IN A POROUS SOLID BODY

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The dielectric permittivity was measured in the frequency range from 5 Hz to 13 MHz for artificial, laboratory-made solid samples of gypsum with different water contents. The two electrode method was used. The measurements were made at three samples with different porosity and structure. The dielectric permittivity of water was estimated from the data by calculations based on the simple mixing law for partial saturation. Two dielectric relaxation times were observed. The second resonance is interpreted as a resonance of the dipoles with a bigger effective moment of inertia. The results are interpreted assuming dipole-dipole and dipole-lattice solid-dielectric interactions and taking into account Debye's theory. The relaxation time and dielectric permittivity of water are functions of reciprocal water volume in a sample (single pore space). The dielectric permittivity of water is a linear function of relaxation time. Spontanous polarization in water is observed.

INVESTIGATION ON PHYSICAL PROPERTIES OF FRACTURED ROCK BY GEOPHYSICAL METHODS

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The aim of our study is to understand the changes occurring in physical properties of rocks owing to ongoing fracturing or fragmentation. Both theoretical and experimental aspects are considered. In particular, we deal with changes of the elastic parameters and the velocities of P and S waves, with the attenuation of seismic waves, and with changes of electrical properties such as resistivity and permittivity. These changes are evaluated in a statistical way. We give examples of measurements in the area of mining activity, which is our main concern. However, these examples bear a more general interest for Earth science, in particular for the prediction of rockbursts and earthquakes. Mining activity most often leads to evolving microcrack systems which can give rise, by means of crack propagation and coalescence, to macroscopic fracture. The examples given show that such processes occurring at first on microscopic scales and finally resulting in a macrocrack can often be monitored by recording the changes in time of the seismic or electrical properties of the rocks in which fracturing or fragmentation occurs.

SIMULTANEOUS MEASUREMENT OF WATER RETENTION AND ELECTRICAL CONDUCTIVITY: TEST OF A TORTUOSITY MODEL

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A conceptual model that accounts for the influence of pore geometry is needed to obtain soil water conductivity from bulk soil electrical conductivity measurements in unsaturated soils. Mualem and Friedman (Water Resour. Res.27(10) 2771-2777 1991) proposed such a model based on the hypothesis that the tortuosity factor affecting the bulk soil electrical conductivity is identical to that defined for prediction of the soil hydraulic conductivity. Soil water retention curves (model input) and bulk soil electrical conductivity (model output) of two soils were measured simultaneously over a range of salinities to test the electrical conductivity model. The model fitted the data of both soils well. The model is suited to obtain the soil water conductivity. Combined research into unsaturated electrical and water flow seems the opportunity to asses tortuosity.

EFFECTS OF STRESS ON PERMEABILITY

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Recent experimental studies will be reviewed to underscore the fundamental differences in the evolution of permeability with deformation between compact and porous rocks. In a compact rock (with porosity < 5% or so), dilatancy and permeability enhancement are generally observed in both the brittle faulting and cataclastic flow regimes. In contrast, porous rocks in the cataclastic flow regime consistently show compaction and permeability reduction with increasing stress. The permeability and porosity evolutions closely track one another. In the brittle faulting regime, the permeability and porosity changes of porous rocks are more complex. Beyond the onset of dilatancy, permeability may actually decrease in a dilating sandstone prior to brittle failure. Microstructural observations have revealed fundamental differences in the pore geometry of rocks of different porosities and failure modes. The pore space statistics can be incorporated into percolation and network models, which have provided important insight into the interplay of damage and tortuosity in controlling the evolution of permeability with the brittle-ductile transition. Implications of the experimental and theoretical results on seismotectonics will also be reviewed.

VARIATION OF WAVE ATTENUATION IN DIFFERENT DRY ROCKS DURING MICRO FRACTURING

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Rock micro fracturing has significant influence on the effective elastic rock parameters and rock strength. In addition to the rock static and dynamic elastic parameters the attenuation of seismic waves is a measure of rock micro cracking and thus can be used for monitoring of rock damage. Experimental data on increasingly damaged rocks and modelling of the attenuation behaviour in terms of crack density and rock damage form a basis for further understanding and utilisation of the attenuation.
Laboratory measurements of ultrasonic wave propagation in dry rocks with different microstructures (granite, tuff, sandstone) were performed during increasing fracturing of the samples. The fracturing was done by applying uni-axial pressure using a constant low strain rate. The observed changes of wave velocity due to the development of micro fractures in the rocks are interpreted by rock models relating velocity changes to changes of crack density. Using the so estimated crack densities as well as the results of additional microstructural investigations the observed attenuation behaviour is interpreted by means of attenuation mechanisms as friction and scattering.

SE39 Physical properties of geomaterials

04 Pore pressure as a geomechanical and geophysical parameter

Convener: Kümpel, H.-J.
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EFFECT OF PORE GEOMETRY ON THERMAL PROPERTIES OF SEDIMENTARY ROCKS

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Knowledge of the thermal properties of rocks is necessary in many applied fields: for geothermal energy extraction, for modeling petroleum generation and migration, and for disposal of nuclear waste, which requires the prediction of generated thermal perturbations. The purpose of this work is to determine the effect of porosity and pore geometry on thermal conductivity of porous rocks. Thermal conductivity of 36 samples of limestones was measured with the divided-bar technique under dry and saturated conditions, and low uniaxial stress. The selected samples are isotropic and mineralogically pure (CaCO3) and offer a wide range of porosity ranging from 0.1% to 38% and cover all kind of pore geometries and degree of consolidation. The results indicate that only flat intergranular crack porosity plays an important role on thermal conductivity, all the other pore geometry (intragranular and intergranular with differents forms [spheroids, ellipsoids, and irregular vugs] and degree of cimentation) have similar effect on thermal conductivity.
The experimental results were compared with the different theoretical and empirical models relating thermal conductivity, porosity and pore geometry. The best fit was obtained with the Zimmermann model.

SEISMIC LABORATORY MEASUREMENTS OF V_P AND V_S ON ROCKS WITH GRANITIC COMPOSITION

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This study presents ultrasonic laboratory measurements of compressional and shear wave velocities up to 500 MPa confining pressure, that have been made on granites and metagranites from the crystalline basement of Western Alps (Northern Italy). The samples of metagranites were in greenschist, amphibolite, and eclogite facies. In order to evaluate the influence of deformation on elastic properties, the samples were collected with different textural characteristics, indicating different total amount of strain.
Seismic velocities are directly correlatable to density, and thus broadly to metamorphic grade. Anisotropy seems not to be determined by the abundance of phillosilicates, but by their crystallographic orientation. This indicates that a partial static recrystallisation does appreciably reduce anisotropy where as a dynamic recrystallisation may increase the anisotropy. It is concluded that seismic anisotropy that is not due to cracks effects may occur in upper to middle continental crust where it is predominantly composed of metagranitic rocks only if there is a consistent regional fabric. The seismic anisotropy may be diminished if postmetamorphic intrusions have caused static recrystallisation.

3D PERMEABILITY TENSOR ESTIMATION FROM MICRO-SEISMIC DATA

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Estimation of the large scale 3D diffusivity of rocks is proposed using the spatio-temporal distribution of the fluid-injection induced seismic events assuming a critical state of stress. During hydraulic-fracturing experiments, a micro-seismic activity has been observed at Soultz, France (HDR Geothermal Site) at a depth ranging from 2800m to 3600m. Several thousand seismic events have been induced in a spatial domain with a lateral dimension of 300m and a depth of 1000m. Similarly, almost 400 microearthquakes were observed during the German Continental-Deep-Drilling Project in the depth interval $9030 - 9100m$. An increase of the pore pressure caused by fluid injection changes the effective normal stress as well as the friction coefficients of the rock mass. Using Biot's equations of the linear dynamic poroelasticity, an estimation of the hydraulic diffusivity D is obtained directly from phase-shift information, considering the distances of the events from the center of the injection interval as a function of the event occurrence times. The hydraulic diffusivity obtained for KTB and Soultz experiments are compatible with the previously known value for the upper crust of the order of $1m^2/s$, supporting the hypothesis that the state of stress in the crust is close to critical, i.e., the crust is on the verge of failure.

BRECCIATION OF A WEAKLY COHESIVE CARBONATE MUD BY WAVE-INDUCED LIQUEFACTION

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The Tithonian (140-135 Ma) of the « Bassin du Sud-Est » (France) shows 10 metre-thick breccia beds made of carbonate mudstone elements within a carbonate mudstone matrix. Brecciation mechanism results from partial liquefaction of a weakly cohesive assemblage of 10^{-6} metre-scale grains under wave cyclic loading related to hurricane wave degeneration on the carbonate ramp.
Microstructural analysis allowed us to establish a three-stages scenario of brecciation: 1) microcracks develop in the mud and clasts are formed when the cracks connect, 2) local liquefaction process creates liquefied mud by reduction of cohesiveness of the cracks edges; the result is a mixture of clasts suspended in a liquefied mud, 3) sedimentation of the mixture involves rearrangement of the clasts.
Cracking and local liquefaction processes proceed from pore pressure increase induced by incremental and irreversible volumetric deformation of the grain framework by grain rotation and grain boundary sliding. These grain displacements are due to shear-stress induced by the action of the waves on the sea floor.
A numerical model allows us to study the liquefaction process at grain scale in terms of pore pressure variations. The model is based on competition between drainage modelled by Darcy's law and interstitial pressure generation modelled by experimentation-derived relationships. Cohesiveness is modelled by a non-linear relationship between the wave cycle number and the shear-stress.

NATURAL POROSITY EVOLUTION IN THE EARTH CRUST: TIME SCALE AND INFLUENCE OF BOUNDARY CONDITIONS

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Accounting of pore pressure evolution at the middle and lower crust is extremely important for geophysical studies. Pore pressure affects on rheology of the crust and seismic velocity. The models are suggested to account pore pressure evolution in two distinguished cases: metamorphic event in the lower-middle crust, and sedimentation. Common point for these two models is a moving upper boundary but boundary conditions are essentualy different. Analytical and numerical results are compared with seismic studies of collision zones and sedimentary basins. Time dependent behaviour of overpressure zones in the deep crust is accounted.

DEFORMATION FIELD AND PORE PRESSURE CHANGES FOLLOWING THE M5.9 ROERMOND-EARTHQUAKE

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Systematic analysis of seismotectonically induced well level fluctuations may be used to improve the knowledge of the role of pore fluids in crustal rheology and earthquake mechanics. We collected records of altogether 194 well level sensors, continuously operating during the M5.9 Roermond-Earthquake of April 13, 1992. About 35% showed a significant coseismic response. The earthquake's static volume strain field at the surface is in reasonable agreement with the sign of the observed well level steps but the amplitudes of the latter show large variations, and exceed those predicted from the wells' volumetric strain sensitivities generally by two orders of magnitude. Obviously, simple models of the crust fail to explain our observations. Our current attention focusses on numerical poroelastic modelling in order to explain the locally irregular pattern of signal amplitudes. These calculations simulate pore pressure diffusion processes caused by rainfall and atmospheric loading in a fluid saturated aquifer. A spatially heterogeneous distribution of pore pressure, which to some extent is equilibrated by the vibrations during the passage of seismic waves, may explain the observed irregular pattern.

DETERMINATION OF HYDRAULIC CONDUCTIVITY AND SUBSIDENCE VOLUME FROM WATER LEVEL MEASUREMENTS DURING BLASTING OPERATIONS

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Tailings created by open-pit mining operations usually have high porosities. Therefore, they are subject to sedifluction. In order to avoid the possible danger of uncontrolled mass movement, blasting operations are a common procedure for compacting and stabilizing the tailings by decreasing porosity. We will present a method to determine the subsidence volume caused by the blasting operations based on water-level measurements.
The experiments were carried out on the former lignite mining site Gräbendorf in Eastern Germany. The distance between the measurement well and the borehole used for the blasting was 44 m. The water levels were measured with high-resolution pressure sensors for several months. This long-term measurement allowed us to take into account the general trend of increasing water levels due to the flooding of the former mining site. We also considered the influence of atmospheric pressure variations on water level fluctuations. However, this influence is small due to the high gas permeability of the tailings site. Based on an analytic solution, we determined the subsidence volume caused by the blasting and the hydraulic conductivity of the test site.

STUDYING THE ROLE OF PORE PRESSURE IN A RIS CASE

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Reservoir induced/triggered seismicity (RIS) is a phenomenon that appears to be directly related to pore pressure changes in the saturated crust - namely through a combination of transient elastic loading and diffusion of excess hydrostatic pressure - but detailed understanding is still poor. A unique opportunity to learn more about the role of pore pressure in this context provides the region between the Koyna and Warna reservoirs in Maharashtra, India. Here, RIS is highest in the world and ongoing for more than 30 years. In a collaborative project we have started to monitor pore pressure changes in that area by recording natural well level fluctuations in an array of (presently) 12 wells. These have been drilled 130 to 250 m into the massive, mesozoic Deccan trap basalts in that region, with the upper 30 to 40 m being cased. Data retrieved so far give evidence that (a) the basalts are water saturated with hydraulic heads typically at depths between 2 and 15 m, and (b) the tapped aquifers are mostly confined, with transmissivities ranging from low to medium (0.01 to 10 m^2/s). Accordingly, most well levels respond to tidal and barometric forces. Longer time series will be screened for (dis)similarities of residual level fluctuations in adjacent wells and for their coherences with reservoir level data and local seismicity.

MODELLING OF COMPACTION IN FAULTED SEDIMENTARY BASINS: INFLUENCE OF DIFFERENT MECHANICAL MODELS ON FLUID PRESSURE

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F.E.M.T.O. (Finite Element Modelling of Transfers during Overthursting) is a 2D model of coupled transport in faulted sedimentary basin, which can simulate the evolution of overthrusting structures. An external kinematics program, like Thurstpack™ from I.F.P., is used to provide the large-scale displacements and deformations due to tectonic forces. Coupling between fluid flow, transport and mechanical behaviour is investigated.
Two approaches are considered. In the first one, porosity is a function of the effective vertical stress. The importance of the fluid overpressure during sedimentation is emphasised. The role of the faults is highlighted and the relevant physical parameters are listed
In the second approach, 2D elastic tensorial mechanics is used. Considering an elastic behaviour of the porous medium skeleton, we examine the friction in the faults of the basin taking into account a friction coefficient constant or depending of the fluid pressure. The coupling between fluid and solid is very important in the basin behaviour, the fluid acting as a lubricant in the mechanical evolution of the basin.

FLUID OVERPRESSURES IN WESTERN MEDITERRANEAN SEDIMENTS

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A compaction model has been developed and applied to five Ocean Drilling Program Leg 161 Sites where overpressured sediments were cored. The sediment porosities were deduced from density log measurements and fluid overpressure were estimated from the difference between the hydrostatic porosity (i.e., the porosity distribution that would have resulted at equilibrium compaction with hydrostatic pore fluid pressures) and these measured porosities. This analysis shows that fluid overpressuring starts at very shallow depths (120-150 mbsf, meters below sea floor) and, in some cases, rapidly increases to lithostatic. The development of fluid overpressures correlates with the presence of gas (mostly methane). Layers filled with free gas are clearly revealed on spikes in the porosity derived from the density log assuming water saturated sediments. The ingredients for capillary sealing, two fluid phases in a layered sequence of fine and coarse sediment, exist in all the overpressured sedimentary sections. Capillary sealing is shown to be quantitatively capable of retaining the overpressures observed.

PORE PRESSURE SIGNALS FROM GREAT DEPTH: CONTINUOUS FLUID LEVEL RECORDS FROM THE KTB, KOLA SG-3 AND ICELAND LL-03 BOREHOLES

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Pore pressure fluctuations e.g. caused by changes of tidal stress or barometric pressure can be observed as fluid level variations in sufficiently deep wells and allow the derivation of in-situ petrohydraulic rock properties. As part of the deep-crustal-lab studies at the KTB-superdeep boreholes (Germany) we are carrying long term (few years) quasi continuous fluid level registrations. Both boreholes are cased except for the lowermost 150 m in 4 km (VB) or 75 m in 9.1 km (HB) depth. The HB appears to be hydraulically damped for periods shorter than several days, yet, the fluid level shows a strong long term drift. Tidal amplitudes of up to 12 cm peak to peak and a clear anticorrelation to atmospheric pressure can be observed in the fluid level of the VB. A 10 day record of fluid level in the Kola SG-3 (open hole 8278-8588 m) shows small tidal signals (few mm) and a weak anticorrelation to air pressure. In cooperation with PRENLAP (Roth, GFZ-Potsdam) a one month data set was recently obtained in the LL-03 (1100 m), Iceland, in a highly seismogenic zone and is presently analysed.

SE39 Physical properties of geomaterials

05 Physical properties of partially molten rocks

Conveners: Dell'Angelo, L.N.; Rosenberg, C.
Co-Convener: Rosenberg, C.

MELT EXTRACTION AND TRANSPORT DURING DEFORMATION

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Migmatite leucosomes and sheetlike bodies of granite in shear zone systems demonstrate the effectiveness of these systems as networks for melt flow in the crust. At melt fractions > threshold permeability during deformation, end member rheological models are percolative melt flow (directed along foliation planes parallel to mineral elongation lineation) and en masse transport of melt with residue (e.g. granular flow); segregated melt migrates down pressure gradients. Crustal-scale transport may be by ductile flow of sheetlike bodies or channelized in tensile and/or dilatant shear fractures formed due to melt-enhanced embrittlement. These processes operate at various length scales, from ~mm to ~km, and timescales, *c.* 10^7-10^{12} secs, under conditions of low differential stress and high fluid pressure. Transport is controlled by the architecture and type of shear zone system. In belts dominated by transcurrent shear, granite arrested during ascent commonly develops C-S fabrics. This suggests percolative flow was not effective in expelling melt, ductile or channelized flow occurred during deformation and granite crystallized during persistent strain. In belts dominated by reverse displacement, granite arrested during ascent generally does not develop C-S fabrics, to imply percolative flow was effective in avoiding buildup of melt pressure. During waning deformation as rates of percolative flow declined, buildup of melt pressure resulted in late-syntectonic ductile or channelized flow and granite crystallized without pervasive penetrative strain.

SE39

MICROSTRUCTURES IN CORDIERITE-BEARING MIGMATITES: INFERENCES FOR MELT SEGREGATION.

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The rheology of partially molten rocks can be roughly described as a two phase system: weak melt and strong minerals. The rheology depends on the volume proportions and, more conspicuous, of the competence contrast of the rheological phases. The viscosities of pure melts have been investigated in the literature, but the mechanical behaviour of the solid phases is nearly unknown under those conditions. Therefore, we investigate solid educts and products of melt producing reactions inside of migmatites from the Bayerische Wald (Variscan belt, F.R.G).
Massive migmatites, without melt segregation, are characterised by a random crystallographic preferred orientation (CPO) of cordierites and the random shape preferred orientation (SPO) of the biotites. These fabrics change dramatic in migmatites, which underwent melt segregation. In melt segregated melanosomes, the cordierites show a well developed CPO and their microstructures indicate intracrystalline plasticity (e.g. dynamic recrystallization). Mineral-composition, microstructures and geothermometry of the recrystallized cordierites demonstrate, that these structures are related to biotite dehydration melting. The quantitative fabric data in different migmatite-types correspond to the modal composition of these different migmatites. This indicates, that the change of mechanical behaviour is direct related to the distribution of melt in the system or to the amount of melt segregation.

DEFORMATION OF PARTIALLY MOLTEN MANTLE ROCKS AT HIGH STRESSES

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The deformation behaviour of partially molten mantle rocks has been investigated by experimentally deforming hot-pressed aggregates of olivine with 2 to 10 wt% MORB. Constant-load compressive-creep experiments were performed to strains of 15-25% at 1200íC and a confining pressure of 200 MPa. At these conditions, the MORB is molten. Differential stresses were varied from 160 to 500 MPa. Stress exponents for olivine+MORB samples of <1.5 and the absence of grain flattening suggest that deformation occurred by diffusive mass transfer and grain boundary sliding. The strength of the samples decreased with increasing melt fraction. Sample stresses exceeded confining pressure in all experiments, but the mechanical data and microstructural observations show no evidence for brittle deformation. The melt is aligned in pockets along grain boundaries oriented at 20í to 30í to the shortening direction. A similar alignment of melt pockets has been reported previously for partially molten dunites deformed at much lower stresses, well below the confining pressure. Olivine without MORB made from the same starting materials was weaker than the partially molten samples, and the stress exponent was 2 for stresses up to 850 MPa where localization of the deformation occurred. This mechanical behaviour is suggestive of semi-brittle deformation and is distinctly different from the olivine+MORB samples. Thus, melt in partially molten mantle rocks appears to inhibit microcracking rather than to promote it.

STRAIN AND FABRIC ANALYSES BASED ON PORPHYROCLAST INTERACTION

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Recent theoretical works (Tikoff and Teyssier, 1994) had shown that analysis of particle imbrication resulting of mechanical interactions between porphyroclasts (or more generally elliptical rigid particles) during deformation provides important information on **strain measure**, **strain history**; and can potentially provides insight into the **conditions of deformation**. Using an efficient multi-scale image analysis tool, namely the Normalised Optimised Anisotropic Wavelet Coefficient (NOAWC) method which is able to detect and quantify the different levels of mineral organisation (grains, clusters or alignments of grains ...) in an image regardless of its size, shape, location and location (Gaillot et al., 1997), we automatically recognise patterns of interacting grains. Results obtained on oriented sections of two granites (Sidobre, France and Mono Creek, California), compared to theoretical models of interacting porphyroclasts in a variety of cinematic conditions, allows us to precise the strain and strain history of the latter massifs.

Gaillot, P., J. Darrozes, G. Ouillon, and M. de Saint Blanquat, M 1997. The normalised optimised anisotropic wavelet coefficient (NOAWC) method : An image processing tool for multi-scale analysis of rock fabric. *Geophys. Res. Lett.*, 24, 14, 1819-1822.

Tikoff, B. & Teyssier, C., 1994. Strain and fabric analyses based on porphyroclast interaction, J. Struct. Geol. 16, 477-491.

FABRIC IMAGE ANALYSIS TOOLS FOR POLYPHASED ROCKS : A COMPARATIVE STUDY

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With regard to the multiplication and generalisation of image processing tools for rock fabric analysis, a comparative study between - **global**, **individual**, **geometric and multi-scale** - approaches is proposed. The chosen method are (1) the intercept method which measure the **global** Shape Preferred Orientation (SPO) of the rock and the strength of the SPO using a rotating network of equidistant parallel lines ; (2) the inertia tensor method which quantifies the **individual** parameters - location, size, shape anisotropy and orientation - of the constitutive parts of the rock and the mean fabric, by computing the individual and mean inertia moment tensor of the image ; (3) the autocorrelation function which furnishies a new image where the rock **geometry** is simplified by convoluting the original image by itself; and (4) the **multi-scale** analysis using anisotropic wavelets allowing recognition and individual quantification -location, size, shape anisotropy and orientation - of each level of mineral organisation (grains, alignments or clusters of grains ...). This comparative study performed on constructed and natural examples, leads to a discussion about significance and possible interpretation of the results for each method. Advantages, limitations and complementarily of these approaches are also discussed.

MAGMATIC DEFORMATION DURING MELT ASCENT IN A DEVELOPING RING COMPLEX (THE LARVIK PLUTON, NORWAY)

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The Larvik pluton represents a ring complex that has been caused either by cauldron subsidence or by multiple injection of magma during the development of the Oslo Graben. The pluton and related dykes were deformed as a crystal mush. This deformation resulted from shearing combined with magmatic flow of crystals near the walls of the magma chamber during the different stages of cauldron subsidence. Olivine, clinopyroxene, amphibole and K-feldspar show high-T deformation structures like coarse grain-boundary sutures, recrystallized grains and characteristic high-T subgrain patterns. Rare low-T features are interpreted as the result of a locally increased strain rate. The deformed crystals are surrounded and enclosed by totally undeformed clinopyroxene-K-feldspar symplectites and by intercumulate nepheline. Both are late products of the restitic melt. This indicates the presence of crystal-mush and absence of solid-state deformation. Because the different sectors of the Larvik ring complex have differentiated in situ magmatic deformation did not only occur during but also after the intrusion of the pluton. In any case, the undeformed intercumulus phases indicate that deformation did not continue during the sub-solidus stage due to a regional stress field.

TOPOLOGY OF METAL MELTS IN OLIVINE AGGREGATES DEFORMED TO HIGH SHEAR STRAIN

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The Earth's core is assumed to have segregated as an iron-sulfide melt from an initially homogeneous Earth. However, high pressure/temperature experiments under hydrostatic conditions suggest that metal melt does not migrate by porous flow at upper mantle conditions due to the high dihedral angle between the olivine and the melt. To evaluate the effect of deformation on the migration of metal melts from peridotites, we studied the effect of shear strain on synthetic aggregates of olivine with varying amounts of gold as an analogue to undifferentiated mantle rock. These experiments were conducted in simple shear at 1250 C and 300 MPa confining pressure, to shear strains of 100-200%. Our initial, undeformed samples have generally equant melt pockets with high (~100) dihedral angles, comparable to that of iron sulfide melts in dunite. Analysis by optical microscopy shows that, after deformation, a large fraction of the gold is in elongate pockets that are oriented about 150 from the maximum principal stress axis and 15 from the shear plane. This orientation is similar to that observed in deformed olivine-basalt aggregates. Currently, 3D x-ray tomographic methods are being used to further quantify the melt geometry.

DIHEDRAL ANGLES AND MELT INTERCONNECTION IN PARTIALLY MOLTEN CRUST: THEORY AND EXPERIMENTS

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Melt distribution at the grain scale is a key factor in controlling the segregation of granitic melts from their source rocks. At low melt fractions, the ratio of grain-boundary energy to solid-melt interfacial energy, γ_{ss}/γ_{sl}, is a fundamental physical property that determines the equilibrium melt geometry, including the dihedral angle θ at a solid-solid-melt triple junction and the permeability threshold ϕ_c, i.e. the volumetric percentage of melt at which melt interconnection is established. At present, the relationship between θ and ϕ_c is only well constrained for idealized, monomineralic systems with single-valued interfacial energies. This presentation will comprise: (1) a review of dihedral angle measurements in quartz-, feldspar- and amphibole-melt systems relevant to crustal anatexis; and (2) an account of the main results of 2-D and 3-D models aimed at characterizing partial melt textures in polymineralic aggregates with anisotropic interfacial energies. On the basis of the very low dihedral angles (10°-60°) measured in all crustal analogues, we shall argue that the permeability thresholds of partially molten crustal protoliths are very low: < 1 vol. % to a few vol. %. Because of the high viscosities of granitic melts, melt segregation is presumed to be inefficient at such low degrees of melting. There may therefore exist a range of melt fractions above ϕ_c over which the partial melt is interconnected but nearly stagnant.

ELASTIC PROPERTIES OF GRANITE UNDER HIGH PRESSURE-HIGH TEMPERATURE CONDITIONS UP TO PARTIAL MELTING

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Motivated by DEKORP data from the Saxonian Erzgebirge the elastic wave velocities of West-Erzgebirge granites from 12 outcrops were measured using 3 different pressure chambers (oil, gas, cubic). The cubic press experiments (0.6 GPa/600 degrees C) show the absence of significant elastic anisotropy and a low velocity differentiation for the investigated samples indicating that seismic reflections cannot be interpreted by contrasts between intrusion phases. The measurements under partial melting conditions (gas pressure 0.5 GPa/1,200 degrees C) with encapsulated samples and selfbuffering demonstrate the strong velocity decreasing effect of small melt amounts. Postexperimental microscopic analysis and digital image processing, performed to find the relation between material/structural and elastic data, showed within microsection scale the heterogeneity and strong volatile control of melt generation and dissipation.

MELT TOPOLOGY IN NATURALLY DEFORMED GRANITOID ROCKS

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The thermal aureole in the Paleoproterozoic Murray Pluton in central Ontario formed by emplacement of the mafic Sudbury Igneous Complex and offers an excellent target for studying partial melt phenomena in heterogeneously strained granitoid rocks. Microstructural analysis of statically crystallized rocks using cathodoluminescence revealed the presence of thin K-feldspar seams at grain boundaries and triple junctions of quartz grains. We suggest that the geometry of the quartz-feldspar boundaries reflects that of the quartz-melt contacts upon reheating of granitoid rock. This is supported by quartz showing rational faces and euhedral shape where completely "wetted" by feldspar as opposed to curved grain boundaries where in contact with feldspar and a second quartz grain. Furthermore, quartz-quartz-feldspar boundaries define a dihedral angle of approximately 35° which is comparable to angles reported from experimentally crystallized quartz-quartz-melt systems but much lower than quartz-feldspar dihedral angles that reached equilibrium in the solid state. By contrast, K-feldspar seams in deformed granitoid rocks are located preferentially along quartz grain boundaries oriented at high angles to the foliation plane. Moreover, dynamically recrystallized quartz grains are locally transected by feldspar seams which indicate fracturing in the presence of melt. Therefore, melt topology was controlled by inter- and intragranular fracturing which occurred contemporaneously with dislocation creep in quartz.

MICROSTRUCTURAL EVIDENCE FOR MELT IN MIGMATITESE

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Microstructural evidence for the presence of melt films and pools similar to those described from quenched partial melting experiments are seldom reported from regional anatectic rocks. Metasediments from the Ashuanipi Subprovince of northern Quebec were metamorphosed at temperatues >900oC and pressures of 6-7 kbar down to 3 kbar. The lower pressures probably reflect melting during exhumation.Some residual rocks contain textural evidence for the presence of melt films and pools. Typically the melt, now pseudomorphed by quartz, forms thin films along grain boundaries and triple points. Very rarely melt also penetrated cracked grains. In some cases residual orthopyroxene has developed crystal faces at contacts with melt. Biotite crystals enclosed in melt are commonly rounded.Preserved melt in regional anatectic rocks may be common. In the Opatica subprovince, K-feldspar pseudomorphs melt films along grain boundaires and triple points in rocks of tonalitic composition. Similar textures were probably common in the rapidly uplifted Wuluma area of central Australia, but later deformation has destroyed much of the evidence.These melt films probably represent the last increments of melt present in the residua. Their presevation may be favoured by rapid uplift and little or no post-melting deformation.

STRAIN PARTITIONING AND PERCOLATION EFFECTS ON THE RHEOLOGY OF PARTIAL MELT AND CRYSTALLIZING MAGMA

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Solid-to-melt and melt-to-solid transitions are not rheologically similar. It rules out a unique rheological critical melt percentage. 4 stages are examined according to melt fraction. 1) The *liquid percolation threshold* connects the melt pockets at 8 % melt. It allows local magma displacement at metric scale. 2) For higher melt percentage (20-25 %), a *melt escape threshold* corresponds to the onset of melt transport over large distances. 3) During magma emplacement, early crystallizing grains (< 20 % solid) rotate and define a fabric. Random loose packing is reached at about 55 % solids and corresponds to the *rigid percolation threshold*. 4) Cluster of particles forms a rigid backbone and can accumulate stress, but the melt can still flow. Local shear zones develop dilatancy and provide the way of rearranging particles near intrusion rims. The system is totally locked at 72-75 % solid, beyond the *particle locking threshold*. LPT and RPT are defined according to the percolation theory. They depend on type, shape and abundance of minerals but not on external forces. Due to the reduced mineral phases, LPT is lower for ultramafic or monomineralic rocks than for felsic rocks. Other thresholds are transitional and depend on deformation and particle shape. The low viscosity melt phase within a viscous matrix induces strain partitioning which increases the vorticity of the system. Shear induced deformation is larger than gravity forces, in segregating felsic melts. It has consequences on textural and chemical equilibrium of the magma during melting and crystallization.

SE39

SE39 Physical properties of geomaterials

06 Physical properties of mudrocks

Convener: Horseman, S.T.
Co-Convener: Urai, J.L.

PHYSICAL AND MECHANICAL PROPERTIES OF COAL AND THEIR INFLUENCE ON THE GEOPHYSICAL PARAMETERS OF ROCK MASS

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The metnods of active control of the stressed state of a rock mass in the vicinity of a working to provide the desirable conditions of its exploitation are known. The one of then which is brodly applied is a preliminary humidifying of a coal seam by a water solution of a surface-active substance (SAS) (Russia's Patent No 2055216). This method is based on the alteration of the physical and mechanical properties of coal due to the intensified growth of the microcracks. Our experiments on the three-axis compression plant (USSR Patent No 1285340) have revealed that the coal subjected to such a treatment develops the plastic properties during the repeated lowering of its strength against the compression. The stresses in the neighbour rock mass become more uniform and are reduced by magnitude. This the probability of rock destruction around the working envelope is reduced, and its stability is enhanced. The technique and equipment for the coal humidifying as well as that for monitoring the efficiency of treatment are developed. The content of water is estimated by the amount of adsorbed, i.e., chemically bound one. For this purpose the NMR technique is used and a portable instrument is designed. The seismographic probing is employed to monitor the stressed-strained state of the coal seam near the working envelope. A hole 10-15 m long and 41 mm in diameter drilled in the coal is seismic signals.

TIME-DEPENDENT SWELLING OF MUDROCKS

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Long term swelling strain records of expansive mud rocks exhibit often a characteristics shape which is conveniently described as a combination of primary and secondary phases. These features of material behavior and current concepts about the microstructural arrangement of clay rich soils and rocks have guided the development of a model based on two levels of structure: a macrofabric in which capillary effects and Darcy type of flow dominates and a microfabric in which basic interaction between minerals and individual particles are responsible for the intrinsic swelling of the mudrock. These ideas have been cast in a mathematical model both from a hydraulic and a mechanical perspective. Transfer of water between both levels of microstructure has been postulated. From a mechanical perspective, swelling strain components due to the hydration of clay minerals have been added to the strain field induced by suction charges. These two constitutive relations have been included into a more general framework for stress strain behavior of partially saturated geomaterials. It has been shown, through a number of sensitivity analyses, that the swelling behavior as predicted by this conceptual model may be specified by means of a reduced number of dimensionless parameters. This is a very convenient feature of the solution which helps in interpretation of laboratory swelling tests (both conventional and suction controlled). The model outlined has been applied to the derivation of basic constitutive parameters for a hard expansive mud rock which is part of the foundation of a nuclear power station.

SOME ASPECTS OF RELATIONSHIPS BETWEEN HYDRIC AND MECHANICAL PROPERTIES OF AN ARGILLACEOUS ROCK

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The importance of pore water on clay behaviour is obvious even in the case of very compact shales. In the framework of researches relative to geological wastes disposal conducted by I.P.S.N., the study presented is based on experimental results obtained on Toarcian Tournemire shales (Aveyron, France). This material is an anisotropic argillaceous rock with very low permeability (10^{-21} m^2) and porosity (<10%) and exhibits the mechanical properties of a rock (R_c=30 MPa). The influence of water potential variations on some aspects of the shale behaviour has been investigated. First of all, the characterisation of hydric transfers has been determined by the application of a large range of suctions. Associated volume measurements allowed the determination of the swelling and shrinking capacities. In this condition, the samples behaviour is of a soil type. Then, a specific experimental device was designed to obtain the swelling pressure under various hydric solicitations. The results show that the swelling pressures are low (<0.6 MPa), and the swelling process is reversible. As well, free swelling rates obtained by application of various salt solutions show that the swelling process is concentration dependent for this particular material. This indicates the existence of osmotic phenomena. Finally, the measurement of coupling coefficients D_t/D_s shows that the results depend on the initial hydro-mechanic conditions; for *in situ* conditions the behaviour is of a rigid material type, and, conversely, the behaviour is of a soil type for a loading cycle beginning with a stress around zero.

COMPACTION BY SYNERESIS: A MECHANISM FOR THE DEVELOPMENT OF POLYGONAL FAULT SYSTEMS IN ULTRA FINE-GRAINED SEDIMENTS

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Compaction in fine-grained sedimentary systems is universally regarded as being dominated by gravitational consolidation during shallow burial. It has recently been proposed that some fine-grained sediments contract volumetrically during early burial and dewatering, based on the structural analysis of polygonal fault systems in Lower Tertiary claystones of the North Sea Basin. A comprehensive review of 27 other compaction-related fault systems was undertaken to test this proposal. In all 28 examples of layer-bound compaction faults, the deformed units were found to be dominantly composed of ultra-fine grained, marine lithologies (smectitic claystones or carbonate chalks) with high porosity and extremely low permeability. The restricted occurrence of this type of deformational response during compaction to ultra-fine sediments is taken to suggest that the deformation mechanism is related to colloidal properties. By analogy with well documented colloidal behaviour in such diverse systems as cheese and polymers, we propose that polygonal faulting is the product of compaction by syneresis, a process whereby pore fluid is expelled from sedimentary gels under the spontaneous action of osmotic or electrochemical forces, rather than under gravity alone. We suggest that the end-products of this type of compactional behaviour are pervasive and areally extensive fault networks in low permeability depositional systems.

THE EXTRACTION AND CHARACTERISATION OF PORE-WATER FROM LOW PERMEABILITY ARGILLACEOUS ROCK SAMPLES

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The French radioactive waste management agency, ANDRA, have been investigating argillaceous and crystalline formations in France to assess their potential suitability for the deep disposal of low and intermediate level radioactive waste. One site at Gard in the South of France has a low permeability Vraconian clay formation of moisture content generally no greater than 10% and typically less than 5%. Hydrochemical characterisation is therefore only possible by studying residual solutes that are physically extracted from pore-waters in preserved clay cores.

The BGS has carried out a number of studies for ANDRA in order to characterise the chemistry of pore-waters at Gard. Data have been obtained using three methods: (i) mechanical squeezing of pore-waters using a hydraulic press; (ii) mechanical squeezing of clay material in which the natural moisture content is increased by the addition of distilled water; and (iii) aqueous leaching of residual solutes from crushed core material. Method (i) is particularly suitable for mudrocks with natural moisture contents greater than approximately 7%. When the moisture content is too low to enable direct extraction, methods (ii) and (iii) have been applied.

The three extraction methods have been applied to samples obtained from two boreholes. Examples will be given of how the three methods have been used to estimate the chemical compositions of *in-situ* pore-water and how these compositions can be used to estimate *in-situ* diffusion coefficients of the clay material.

BEHAVIOUR OF COMPACTED CLAY UNDER HIGH GAS PRESSURE

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It is well established that during the disposal lifetime of High-Level Nuclear Waste repository in a deep geological formation, gas will be generated mainly by the anaerobic corrosion of metal. For the French disposal concept, gas could accumulate in the space between the waste steel overpack and the compacted clay barrier. In order to characterise the behaviour of the engineered barrier, the French Atomic Energy Commission (CEA) has carried out an experimental programme on H_2 gas migration in the smectite-rich (Fo-Ca) reference clay. Gas permeability tests were performed on clay specimens with dry densities between 1.6 and 1.9 g.cc^{-1} and for water saturation degrees between 70% and 100%. Gas entry and gas breakthrough pressures were also measured during extended gas migration experiments. These threshold pressures are probably associated with the creation and propagation of preferential pathways governed by the hydro-mechanical properties and the stress state of the clay. Complementary work was performed in modelling the gas pressure at the overpack-engineered barrier interface and in comparing it to the gas breakthrough pressure. This was made possible by integrating the results of recent studies in this area which suggest that breakthrough pressure roughly corresponds to the sum of clay swelling pressure and external water pressure. The conclusion was reached that gas breakthrough pressure and estimated gas overpressure in the near-field of the repository are of the same order of magnitude and that gas is a key issue for clay engineered barrier performances and thus for disposal safety.

CONSOLIDATION-INDUCED RADIONUCLIDE RELEASE FROM A HLW REPOSITORY IN THE OPALINUS CLAY IN SWITZERLAND

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Nagra is investigating the feasibility of siting a deep geologic repository for high-level waste (HLW) in the low permeable Opalinus clay formation in Northern Switzerland. One of the issues in the performance assessment is the effect of consolidation of the Opalinus clay on the long-term repository safety. Consolidation is induced by future glaciations or by a variation of the thickness of the overburden due to sedimentation or erosion. As a result, a transient groundwater flow occurs, leading to radionuclide migration from the repository towards the higher permeable formations below and above the Opalinus clay. Preliminary calculations were carried out using Terzaghi's linear theory of reversible consolidation in one and two dimensions, with the objectives of i) determining the time-dependent Darcian flow field, ii) estimating the radionuclide migration rates, and iii) identifying important parameters by performing a sensitivity analysis. The model domain consists of a vertical section of the horizontal Opalinus clay formation. Radionuclide migration is calculated by considering advective transport in fractures and vertical major faults due to consolidation-induced transient flow.

CHEMICO-OSMOTIC FLOW, SWELLING AND HYDRATION IN SHALES

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Chemico-osmotic flow may be defined as the movement of water molecules down the chemical potential gradient of the water. This flow can be either advective or diffusive. Since the chemical potential of free water can be lowered by the addition of solutes, osmosis can occur when two aqueous electrolyte solutions of differing concentrations are separated by a semipermeable membrane. Membrane properties of compact clays are thought to be due to electrical restrictions on the movement of the solute ions through the narrow pore spaces between negatively-charged clay mineral surfaces. The chemical potential of water can also be lowered by adsorption onto solid surfaces. Heat is given off by the exothermic hydration reaction and the water undergoes a change in enthalpy. Water movement from thicker adsorption films towards thinner films can be regarded as a second form of chemico-osmosis. These concepts are illustrated by a programme of experiments on Opalinus Clay from the Jura Mountains of northern Switzerland. Shale discs were equilibrated with an NaCl solution under triaxial confinement. Each disc was arranged so as to form a membrane between reservoirs of dilute brine and distilled water, with the two reservoirs at the same pressure. The flux of water was measured with great precision. The system exhibited transient flow, accompanied by swelling. The results provide indisputable evidence for the existence of an osmotic flux of water in shale membranes subject to a salt concentration gradient.

AN *IN SITU* GAS INJECTION EXPERIMENT IN THE MERCIA MUDSTONE, KEYWORTH, ENGLAND

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The mechanisms controlling gas migration through mudrocks are not fully understood. The high surface area, small size and generally uncemented nature of the clay particles introduce complex reactions including physico-chemical, hydration and interfacial phenomena. These forces are not accommodated in current two-phase flow or fracture theory. To investigate these reactions and examine possible scale effects between laboratory and field measurements a series of gas injection field tests were performed. A radially-configured borehole array was drilled in the top 4m of the Mercia Mudstone Group rocks on the Keyworth site. This was instrumented with tensiometers at distances of 0.5, 1.0 and 3m away from the injection device. Prior to gas injection the formation around the injection piezometer was left for 7 months to allow re-equilibration of *in situ* stress and groundwater pressures. During injection upstream gas pressure was monitored with time and the resultant curves were found to be very similar to results obtained in laboratory tests. Gas entry was associated with the formation and dilation of pre-existing or induced pathways. The sudden ingress of immiscible gas caused a clear hydrodynamic signature measured spontaneously in all tensiometers. Gas flow was shown to be pressure and flow rate sensitive above a capillary threshold. The results of this experiment lead us to question the validity of conventional two-phase flow modeling approaches when applied to compact clay-rich media.

ION EXCHANGE, WATER UPTAKE, SWELLING AND SWELLING PRESSURE OF MX-80 BENTONITE IN HIGH SALINE BRINES

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The running project is directed towards a model which quantitatively correlates swelling pressure, the amount of adsorbed water, and brine composition. Assuming that the wateruptake is governed by the ion adsorption from the salt solutions and that a positive correlation exists between the interlayer water content and the swelling pressure an experimental programme was set up that comprises the direct measurement of the ion exchange equilibria, the amount of adsorbed water, the interlayer swelling and the swelling pressure. The employed techniques will be discussed and preliminary results will be presented. These results show, that the water uptake, the swelling and the swelling pressure are highly influenced by the amount of Mg in the brines. The higher the Mg content the higher are the interlayer spacings and the resulting swelling pressures.

Controlled suction oedometric tests on Boom clay

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Boom clay is studied as a potential host material for high level radioactive waste repository. In this frame, it is important to characterise the behaviour of this material during the different phases of a repository building (excavation, lining installation, sealing). Controlled suction oedometric tests have been done to obtain hydro-mechanical parameters of unsaturated Boom clay. These tests have been made on fresh Boom clay sample and on compacted dry Boom clay powder, and they will be compared in this paper. The sealing phase will be developed: desaturation of the host rock due to high suction potential of the sealing material , increase of the stress due to the swelling pressure of the sealing material. Some connection will be made with the geomechanical model of Alonso and Gens.

LOCAL OFFLOADING OF THE OUTBURST-HAZARDOUS COAL SEAMS BY THE PREPARATIONAL WORKINGS

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The formahion of a region of lowered stresses around the field working depending on the level of geostatic stresses and physical and mechanical properties of the enveloping rock is discussed together with its possibility to obtain a local offloading of the outburst-hazardous coal seams. The results of the analytical studies and the introduction of this technique.
The offloading effect of the field working on the outburst-hazardous coal seams in the mines of the Central Region of Donbas was used during conducting of more than 5000 m of breakage workings without taking the preventive antioutburst measures.

SE39

COUPLED TRANSPORT PHENOMENA IN THE OPALINUS CLAY (SWITZERLAND): FIRST ESTIMATES OF SOLUTE FLUXES

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First estimates of the potential role of several coupled transport phenomena on solute and fluid transport, in the context of a high level waste repository hosted by the Opalinus Clay, have been made. The solute fluxes associated with hyperfiltration, chemical osmosis, thermal diffusion, and thermal osmosis, have been compared to the fluxes associated with chemical diffusion and advection. These estimates suggest that thermal osmosis is the coupled transport mechanism that could have a strong impact on solute and fluid transport in the vicinity of the repository, even under the low temperature gradients expected at the time of waste canister failure ($t \approx 1000$ y). The results from a simple one-dimensional transport simulation suggest that the impact could become significant if the thermo-osmotic permeability of the Opalinus Clay were larger than 10^{-12} m^2/K/s.

VELOCITY DEPENDENT BEHAVIOR OF CLAY GOUGE

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Recent studies have shown that even small amounts of weak minerals, like clay or phyllosilicates, affect fault strength significantly. It tends to be lowered toward the strength of the weaker minerals. Shearing experiments on simulated clay gouge 0.5 mm thick, between three blocks of granite, were employed to investigate how the mechanical properties of faults are controlled by the strength and behavior of phyllosilicates. A biaxial testing machine was set up under room temperature, 10 ~ 50 MPa normal stress and then changing ten times from 0.0014 ~ 14 μm/sec in slip velocity. The samples used were two montmorillonites, one kaolinite, and one chlorite, each being typical of each clay structure. All runs suggested linear relations between normal stress and shear stress, that indicates the friction laws were followed. However, especially at lower velocity, their behavior of patterns did not follow Dieterich's frictional constitutive law. Kaolinite and chlorite gouge showed relaxation behavior at low velocity (< 0.14 μm/sec), while the two montmorillonite gouge indicated strain hardening so estimating the dehydration effect of absorbed water in the layers of the montmorillonite. Additionally, we observed chlorite gouge behavior indicating both friction and flow (intragrain slip) occurring simultaneously. We propose that such differences of clay behavior occur even under room temperature.

CHARACTERISATION OF ANION DIFFUSION IN A SILTITE FORMATION (MARCOULE, FRANCE) : THROUGH-DIFFUSION EXPERIMENTS AND INTERPRETATION OF IN-SITU CHLORIDE AND BROMIDE PROFILES.

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The French radioactive waste management agency (ANDRA) has been investigating a siltite formation at Marcoule (France). The very low permeability of the rock, and small hydraulic gradients of the site, make it likely that diffusion is the main transport phenomenon governing solute movement in the formation. In order to study this hypothesis, two different approaches were employed to characterise the diffusion properties of the rock :
- through-diffusion experiments, using both tritiated water (HTO) and iodide tracers, were performed on siltite core samples from two boreholes,
- the concentration versus depth profiles of chloride and bromide extractable by water leaching of borehole siltite samples were interpreted using a pure diffusion model. The initial composition of the pore water was assumed to be sea water and that of the upper and lower bounding formations to be freshwater; the starting time, to, was set equal to the geological age of the formation (100 My). The computer model was then used to fit the experimental chloride and bromide profiles by adjusting the values of the pore diffusion coefficients.
Reasonably good agreement was observed between the values measured in the through-diffusion experiments and those obtained by fitting the extracted concentration profiles.

SE40 Petrophysical control of anthropogenic and natural Earth's processes

Convener: Huenges, E.
Co-Convener: Safanda, J.

THE MONT TERRI UNDERGROUND ROCK LABORATORY : A NEW INTERNATIONAL RESEARCH PROJECT IN SHALE

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In many countries, argillaceous formations are considered as potential host rocks for repositories of radioactive waste. Therefore, in 1995 several organisations decided to start an international research project in the reconnaissance gallery of the Mont Terri motorway tunnel in a Jurassic claystone/shale formation. The project is under the patronage of the Swiss National Hydrological and Geological Survey, partner organisations are Nagra (Switzerland), ANDRA and IPSN (France), SCK•CEN (Belgium), BGR (Germany), ENRESA (Spain), PNC and Obayashi (Japan). The aims of the project are to analyse the hydrogeological, geochemical and rock mechanical properties of an argillaceous formation and to evaluate and improve investigation techniques. 15 experiments were started in 1996 in 64 boreholes of maximum 30 metres length. Early 1998 a new gallery of 250 m length will be excavated to host further experiments. Key issues addressed in the experiments are solute migration mechanisms (role of faults), mechanical evolution and hydraulic properties of the excavation disturbed zone, porewater extraction and characterisation techniques, chemico-osmotic and thermal effects, two-phase flow mechanisms and self-healing mechnisms in fractures.

CLAY INJECTION INTO NORMAL FAULTS: FIRST RESULTS FROM FINITE ELEMENT MODELLING

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Lateral clay injection in normal faults in layered sand - clay sequences is the major process by which unexpected amounts of clay can be added to the fault gouge and change the transport and mechanical properties drastically. We present the preliminary results of geomechanical modelling using the finite element technique with elasto-plastic continuum elements and interface elements. We start by assuming the presence of a releasing bend in a clay layer, based on the model of Lehner and Pilaar (1997). We performed 2D simulations of a layered sand-clay system (where the sand layer is always stronger as the clay layer), where the pre-existing releasing bend in de clay is represented by interface elements.
First results of simulations with drained behaviour show that the criterion for the onset of clay injection can be given by: C=(rho*g*h*(1-sin phi))/(2cos phi), where C is cohesion (MPa), rho is average density of sand and clay (kg/m^3), g is the acceleration of 9.81 m/s^2, h is depth (m) and phi (deg) is internal friction angle.
The extrusion of clay exerts a drag on the sandstone adjacent and lowers the horizontal stress in the sand. Deformation within the clay layer tends to be concentrated on the sand-clay interface.
Further work will concentrate on applying these results to more complex fault structures observed in nature and in scaled model experiments.

PETROPHYSICAL PROPERTIES OF SANDSTONE IN FACIES AND PALAEOTECTONIC RECONSTRUCTIONS

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Theoretical dependence of sandstone's porosity on its natural and mineralogical density and specific surface area have been studied using sandstones from the Ufimian Stage of the Permian.

Correlation between calculated and experimental dependences permitted to gain information on average mineralogical density (sandstone composition) and its changes within the south-east Tatarstan, Russia, pore size spectrum, and spatial grain arrangement.

The study resulted in palaeogeographically important reconstruction of the conditions of sandstones' formation (from wash-down sources to the hydrodynamics of sedimentation environment).

IN SITU THERMAL CONDUCTIVITY AND ITS IMPORTANCE FOR HEAT-FLOW STUDIES: AN EXAMPLE FROM A SEDIMENTARY ENVIRONMENT

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In the US Midcontinent, the sedimentary succession consists of lower Paleozoic carbonates interbedded by a Devonian-Mississippian black shale unit and overlain by a thick series of upper Paleozoic alternating thin-bedded carbonates and shales. The fissility of the laminated shales is caused by the horizontal orientation of clay particles and impedes vertical heat flow. In general the measurement of thermal conductivity (k) for shales is problematic using the chip technique because of no way to evaluate the anisotropy impact on the k value. In our study the cuttings determined k values for shale sections using an in situ porosity of 10±5% were 1.8-2.25 W/mK in contrast to an heat flow inferred, average k value of 1.18 W/mK. We show that k values (1) measured on cuttings and (2) determined from a suite of conventional wireline logs can be used in conjunction with a precise temperature log to evaluate the heat flow along the borehole profile, from which a realistic in situ k value for the different shale units can be inferred. The well-log analysis showed that a statistically significant equation for the matrix k of carbonates was computed from a multiple regression on volume of shale and rock density. The equation $k = 8.45 \times RHOmaa - 4.64 \times Vsh - 18.66$, based on the laboratory matrix k, was valid as shown by conversion of the matrix values to bulk, in situ k values and by modeling similar temperature-depth curves as they were logged.

ESTIMATING FLUID FLOW BEHAVIOUR IN MID - CRUSTAL DEPTH DOMAINS

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In-situ permeability structures at greater crustal depth can be generally only assessed indirectly by analysing the impacts from a corresponding flow field. Fluid flow behaviour is strongly dependent on the state of pressure and temperature as well as of chemical composition. With the intent of technical application, physical chemistry laboratories have extensively analysed since long time the fluid properties under various physical conditions. Application of their results allows also to estimate the behaviour of the fluid transport properties such as density, dynamic viscosity and diffusion coefficient over large temperature and pressure ranges.

In the presented approach the impacts on the flow field of a geophysically confirmed (thermal) anomaly in the upper mantle are investigated by combining the non-linear fluid properties with measurements of rock properties. The analysis is grounded on near surface observations of the thermal and CO_2 flux fields as well as on structures highlighted recently from the KTB drilling project. It is especially intended to elucidate possible effects on flow pattern and velocity in the upper and mid crust. The implications of such simulations indicate very efficient transport of chemical substances over large horizontal (i.e. >20 km) distances however a rather limited effect on the temperature field.

SE41 Electro-magnetic and electro-kinetic properties of rocks: integration of laboratory, borehole and field measurements

Convener: Glover, P.W.
Co-Conveners: Revil, A.; Stoll, J.B.

PERMEABILITY-POROSITY RELATIONSHIP FOR SEDIMENTARY, IGNEOUS AND METAMORPHIC ROCKS ON THE BASE OF FRACTAL PORE SPACE GEOMETRY

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Several borehole measurements and combinations of them can be interpreted for porosity ϕ. However it is much more difficult to obtain estimates of permeability k. Although, in principle permeability may vary independendly of porosity, a k - ϕ relationship can be established, if additional information of the pore structure is available. The approach starts from the KOZENY-CARMAN equation, which relates permeability to porosity ϕ, tortuosity T and effective hydraulic pore radius r_{eff}. Using fractal models of the pore space it is possible to replace T and r_{eff} by functions of ϕ, where the fractal dimension D of the structure is a fundamental parameter. The result is a general permeability equation which was calibrated for several types of sedimentary, igneous, and metamorphic rocks. These relationships were applied to aquifer and reservoir sandstones, and to the gneisses and metabasites of the KTB (Continental Deep Drilling Program) in order to calculate permeability logs from porosity data.

How dilatant is rock salt?

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Salt structures are primary candidates for underground cavities or radioactive waste disposal sites. Although dilatancy, that is, the opening of microcracks, is most important for the transport properties in rock salt, little is known about its effectivness under PT-conditions. In order to investigate the deformation behaviour of rock salt, combined measurements of ultrasonic P and S wave velocities and permeability have been performed on natural core samples during triaxial deformation (compaction and extension), ultimately to determine the boundary between the dilatant and compressive stress domains ("dilatancy boundary").

Measurements on intact rock salt samples give extremely low permeability values, usually below the resolution of the test system ($<< 1*10^{-20}$ m^2). At confinining pressures <10MPa and deviatoric stresses exceeding a critical limit the deformation in rock salt is accompanied by the onset of dilatancy followed by a permeability increase of several orders and a coeval decrease of wave velocities. With increasing confinining pressure the effect of dilatancy is progressively reduced indicating a „brittle-ductile transition" in rock salt.

APPLICATION OF THE NONLINEAR IP EFFECT TO DETECT MINERALIZED SHEAR ZONES

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Spectral measurements of the complex conductivity permit the determination of electrochemical parameters of rocks in dependency of the mineralogical composition. While the induced polarization (IP) is usually treated as a linear process, large bodies of interconnected electric conducting mineralizations cause nonlinear current-voltage-characteristics. It is suspected that the reasons for this behaviour are electrochemical processes on the surface of the electric conducting material.

Laboratory measurements confirm this effect: When a monochromatic periodical current is injected into an electrolytic trough containing a graphitic cylinder as electric conductor, significant harmonics of the fundamental period are observed in the potential differences nearby. This method of the spectral impedance measurements is very sensitive and permits the detection of the nonlinearity at relatively low current intensities.

The nonlinear IP effect was also observed within the framework of a field survey at a drill-hole near Rittsteig (Bavaria, Germany) indicating a steeply inclined interconnected electric conducting layer.

METHOD OF SEISMIC-ELECTRIC EFFECT USED ON REFLECTED WAVES.

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The seismic-electric effect (SEE) is the appearance of electric field tension between two points where the gradient of pressure exists in moister-saturated porous rocks along elastic wave propagation. SEE nature relates to electric-kinetic phenomena in binary electric layers on the solid / liquid interface. For the first time SEE experiment was carried out on reflected waves either in laboratory or field conditions. The source of elastic waves are repeated hammer blows or power bimorph piezoelectric ceramic impulses of 1 kHz major frequency, receiver - electrodes, following with electric amplifier and refined registering device with sensitive magnetic film. Due to integral SEE value formation along acoustic wave propagation the SEE signals of 30-200 mkV are perfectly distinctly traced on a receiver that is advantage for treatment. The method worked in cases of harsh reflecting frontiers yet. Depths from 0,1 to 15 m were reached. For the first time the method was successfully applied to determine the thicknesses of covering sedimentary layers of deep cave interior and to outline dome cavities in karst massifs. In similar difficult attainable places the method is preferable to be used for it doesn't require a complex apparatus.

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ELECTRICAL POTENTIAL SIGNALS FROM ROCKS UNDERGOING DEFORMATION UNDER SIMULATED CRUSTAL CONDITIONS

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Electrical potential changes measured in the earth's crust have been suggested as possible precursors to earthquakes and volcanic eruptions. Most recently, there has been considerable debate on the significance of the predictions made using the VAN method in Greece. In general, there has been a paucity of good quality data, and hence the mechanisms generating the electrical signals are still not fully understood. Currently proposed mechanisms include; electrokinetic phenomena, piezoelectric effects and contact electrification. We present results from laboratory triaxial deformation experiments on samples of sandstone, basalt and limestone under simulated crustal conditions in which both electrical potential and acoustic emission were measured simultaneously. The acoustic emission signals allow us to track how electrical potential changes as deformation and fracture proceeds. Our results show that clear, precursory electrical potential signals are generated during these experiments. The signals are attributed to both electrokinetic and piezoelectric phenomena, with the electrokinetic effect appearing to be the dominant generating mechanism.

ELECTROOSMOTIC PHENOMENA IN POROUS MEDIA

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A general theory of electroosmotic phenomena in spatially periodic porous media was developed. The electric conductivity, permeability and coupling electroosmotic tensor coefficients are obtained in terms of solutions of several transport unit cell problems, posed for the linearized electrokinetic equations. By means of a consistent application of the homogeneization methods, the Darcy-scale equations describing the electroosmotic flow in a spatially periodic porous medium are obtained. A numerical code has been built, with an overall precision better than a few percent, when the double layer thickness is larger than the elementary grid size. It gives reliable results in the mostly unexplored range of Debye-Hückel lengths comparable to the pore radius; hence, the results are applicable to finely dispersed media, such as clays. Several model porous media have been systematically investigated, including regular arrays and random packings of spherical and ellipsoidal particles, and reconstructed media. A new correlation between the electroosmotic coupling coefficient and permeability is proposed for thick double layers, which compares successfully with experimental data.

SEISMO-ELECTRIC PROPAGATION IN POROUS MEDIA: FIELD EXPERIMENTS AND THEORETICAL STUDIES

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In fluid-saturated porous media, various couplings between mechanic and electromagnetic energy may occur. An interesting type of coupling is produced by seismically induced electrokinetic effects in the seismic prospecting (0-100 Hz) frequency band. These effects can be observed with electric dipoles connected to a standard multichannel seismic acquisition system. Field experiments carried out over a shallow aquifer show that the dominant seismo-electric effect recorded at the surface is an electric field accompanying the seismic waves with significant contributions of surface waves.
In order to improve our understanding of seismo-electric effects and investigate their potential for the detection and characterization of fluids at shallow depth, we have extended the generalized reflection and transmission matrix simulation method to account for the coupled seismic and electromagnetic wave propagation in layered porous media. Our computer code is based on Pride's macroscopic governing equations which couple the Biot theory and Maxwell equations via transport equations. This simulation program is especially useful to study the sensitivity of the electric fields and electromagnetic waves converted at depth to the physical and chemical properties of porous media, notably the characteristics of the fluid phase.

RESULTS OF FIELD, BOREHOLE AND LABORATORY ELECTROMAGNETIC MEASUREMENTS IN AN OIL-GAS DEPOSIT IN NORTHERN UKRAINE

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The study area was 40X20 km large in northern board part of Dnieper-Donetsk Depression. The main part of field prospecting by MTS, FDEM and IP was made before drilling i.e. without distortions from boreholes. Results of the field EM data interpretation were used for borehole site choosing. Electrical logging yields variability of longitudinal ρ_l and transverse ρ_n apparent electrical resistivity in 14 stratigraphic horisons from one borehole to another. Analysis of all the data proves that the presence of oil and gas increases ρ_l at 10-30%, ρ_n -at 10-50%, anisotropy ρ_l / ρ_n at 10-150%. The changes are noticeable for field prospecting EM techniques, that was practically confirmed by a detailing field survey. High resolution of FDEM is provided by a relative method of phase measurements an original technique of subsurface inhomogenieties accounting.

STREAMING POTENTIAL MEASUREMENTS ON VOLCANIC SAMPLES.

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Geohysical phenomena prior to volcanic eruption, particularly changes of self-potential or magnetic field, have been observed in volcanic area. Laboratory measurements were performed in the scope of using electrokinetic phenomena to monitor the processes of fluid flow occurring during volcanic activity.
The streaming potential, due to fluid circulation, was measured on intact saturated samples from Montagne Pelée volcano. It was found to be proportional to the driving pore pressure.
Streaming potential and electric conductivity have been measured in laboratory on 12 samples of permeability ranging from 146×10^{-15} m^2 to 34×10^{-12} m^2. Measurements showed electrokinetic coefficients in the range -1.3 to -109.8 mV(MPa.Ω.m)$^{-1}$. Streaming potential has been found to depend on transport properties as permeability and formation factor, although such a dependence is not described in theory. This dependence is not induced by a surface conductivity, and various global zeta potentials from -1.9 mV to -156.9 mV depending on rock consolidation would be required to explain such transport properties dependence.

THE POSSIBLE JOINT APPEARANCE OF PRE-SEISMIC GEOCHEMICAL AND GEOELECTRICAL ANOMALIES IN TECTONICALLY ACTIVE AREAS

Giovanni Martinelli*

Literature data and direct experimental evidences report about the contemporary possible recording of precursory/coseismic phenomena geochemically and geophysically generated.Deep seated fluids can generate geochemical and geophysical anomalies when displaced by thermally or mechanically induced gradients.Electrokinetic processes can explain a consistent part of the observed self potential phenomena.
Fluid motion laws can similarly explain observed geochemical anomalies if chemical reaction rules are considered.Different behaviour in laboratory experiment have been observed in fluids able to generate geochemical and geoelectrical anomalies in connection with pH changes.The observed behaviour can be potentially useful in field data interpretation when fluid carrier is dominated by CO_2.Possible anomaly generator geochemical reactions are discussed.It turns out to consider essential to simultaneously monitor geoelectrical and geochemical parameters in earthquake precursory related researches

CONCLUSIONS FROM MULTICHANNEL ELECTRICAL RECORDINGS IN A STANDING TREE

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In this paper eight-channel electric data series, have been recorded for about one year by using small-size stainless steel electrodes in a trunk of an Austrian/Turkey oak tree (Quercus cerris) standing in the Nagycenk Geophysical Observatory are presented. The electrodes are situated at two height levels (4m and 6m) and in four directions (N, E, S and W) of the about 50 years old tree. At the observatory all important environmental parameters are continuously measured, so the reaction of the tree to any change in environmental parameters can be directly seen. The existence of a sinusoidal variation of a period of one day, detected at first by Morat P., Le Mouel J-L., Granier A., 1994, Compte Rendu, Life Sciences, 317, 98-101) has been confirmed and studied in details. Its seasonal amplitude variation seems to be in a close relationship with the sap-wood activity of the tree. The observed phase shifts between different channels refer to the complexity of the phenomenon. The main question is whether the sap-wood movement within the tree can be estimated by using an electro-kinetic approach.

ON THE PIEZOELECTRIC PROPERTIES OF ROCKS, ORES AND MINERALS

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The classification of rocks, ores and minerals in according to their piezo-activity is presented. This classification based on the long-standing study of piezoactivity of ore-quartz, pegmatite, galenite-sphalerite and other deposits. There were revealed four main groups: (1) high-active – the value of piezoactivity (d) of rock, ore and minerals is more than $5.0 \cdot 10^{-14}$ C/N; (2) medium-activite – $0.5 \cdot 10^{-14}$ C/N ($0.5 \cdot 10^{-14} < d < 5.0 \cdot 10^{-14}$); (3) slightly-active – $d < 0.5 \cdot 10^{-14}$ C/N; (5) non-active – $d \approx 0$. The laboratory and field measur- ements of samples verify the regularity, fixed before. For example, the greater sizes of minerals' grains, the higher its piezoactivity and on the contrary. The measurement of piezoelectric activity of samples of quartz permits to carry out genetic classification of different types of ore-quartz deposits. The most extensive group of all investigated deposits is a gold-quartz one. The values of piezomodules on those deposits are changing over the broad band. High values of piezomodules were registered for the gold-quartz deposits of mesothermal type, where they reach $35.0 \cdot 10^{-14}$ C/N. Epithermal deposits have usually low piezoactivity. The pegmatite deposits are presented by three types: crystallocarrying, raremetallic and micacarrying. The piezoelectric activity of polymetallic and apatite-nefeline deposits is also given.

SE41

STREAMING POTENTIAL MEASUREMENTS WITH CRUSHED ROCK SAMPLES AND ROCK SAMPLES DURING DEFORMATION AND RUPTURE

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The ζ potential has been measured with crushed rock samples as a function of pH and electrolyte concentration for various salts. The measured value for crushed Fontainebleau sandstone at pH=5.7 and an electrolyte resistivity of 400 Ωm was found to be -47 mV. The ζ potential has been observed to be sensitive to the valence of the ions, and is approximately reduced by the charge of the cation. The set of empirical laws derived from our measurements can be used to assess the magnitude of the streaming potentials expected in natural geophysical systems.
Streaming potentials and resistivity measurements have been performed on Fontainebleau sandstone and Villejust quartzite samples in a triaxial device during compaction, uniaxial compression and rupture. Measurements on individual samples do not show any clear intrinsic dependence of the streaming potential coefficient on permeability. An apparent dependence of the streaming potential coefficient with permeability is however observed during compaction. Before rupture, an increase of the streaming potential, associated with the onset of dilatancy, was observed for three samples of Fontainebleau sandstone and one sample of Villejust quartzite. Consequences for the observation of streaming potential variations before earthquakes are discussed.

CLASSIFICATION OF PIEZO- AND ELECTROKINETIC PHENOMENA

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The results of investigations of piezo- and electrokinetic potentials, appearing in rocks under the action of elastic waves or static pressure are presented. On the basis of long-standing both field and laboratory investigations carried out in different geological-geophysical conditions a new classification has been proposed. The classification includes: (a) electrokinetic effect (E), resulting from electrization of rocks under a relative displacement of solid and liquid phases; (b) piezo-electric effect as a result of electric polarization of piezoactive rocks; (c) near-shot effects occurring in a zone of elastic waves' excitation due to the breakage of rocks and ionization of the products of explosion and air; (d) effect (I) reveals itself in the change of the strength of current passing through the ground owing to the change of the electroconductivity of rocks; (e) the total manifestation of electrokinetic effects E and I is seen in twophase media under the conditions of natural and artificial electric fields; (f) high-frequency impulsive electromagnetic radiation due to polymetallic ore bodies themselves. It is suggested to use the above-mentioned parameters in applied geophysics. The piezo- and electrokinetic phenomena may be used also for prediction of earthquakes.

ELECTRIC POTENTIAL VARIATIONS ASSOCIATED WITH YEARLY LAKE LEVEL VARIATIONS

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Electric potential variations are recorded since November 1995 at 14 measurement points on a one-km wide ridge separating two lakes in the French Alps. The levels of the lakes vary by several tens of meters on a yearly cycle, inducing stress variations and fluid percolation. The measured electric potentials are observed to be stable except at one point where unambiguous variations as large as 120 mV are observed over a year, linearly correlated with the levels of the lakes, with a magnitude of 2 mV per meter of water. This particular measurement point lies at the edge of a SP anomaly, which supports the presence of a localized zone of ground water flow forced by the lake level, suggesting an electrokinetic mechanism. The observed correlation implies a ζ potential of -6.6 mV for a 60 Ωm electrolyte at 25°C, in agreement with laboratory measurements

STREAMING POTENTIAL MEASUREMENT AS A PRECURSOR TO FAILURE.

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Geophysical precursors to earthquakes, particularly changes of electric potentials, have been observed in seismic area. These changes could be explained by the effects of dilatancy, caused by stress variations in the vicinity of the source, which change the cracks and fluid distribution, and affect the resistivity, the permeability, and the streaming potential. The streaming potential, due to fluid circulation, was measured in laboratory on intact saturated sediments. It was found to be proportional to the driving pore pressure. The electrokinetic coupling coefficient, which is the ratio between the streaming potential and the excess pore pressure, was found to be proportional to the fluid resistivity. For a fluid conductivity of 10^{-3} S/m, this coupling coefficient varies from 10 mV/0.1 MPa to 6642 mV/0.1 MPa, when the permeability varies from 0.15 10^{-15} m^2 to 1220 10^{-15} m^2.
Fontainebleau sandstone samples were deformed under triaxial stress up to failure with water being made to flow during the deformation. The main variation of the electrokinetic coupling coefficient was a large increase beginning with the onset of the localization, at about 75% of the yield stress. This increase was thought to be due to an increase in the global zeta potential in the shear zone when new cracks were created and connected.

USE OF ELECTRO-KINETIC PHENOMENA FOR MONITORING OF MODERN PROCESSES IN LITHOSPHERE.

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Precision total force permanent magnetic field observations were organized in two different regions of the former USSR with the goal of study the modern geodynamic processes in lithosphere. The first area is seismically active regions of Uzbekistan, the second - practically aseismic countries of the Urals. The data of Uzbek network of 35 permanent protonmag stations were successfully used for earthquake prediction while Uralian information were employed for geotectonic mapping of the country. Theoretical calculations of electro-kinetic effects, streaming potential and investigations electro-kinetic properties of rocks in laboratory made it possible to construct models of the sources of observed anomalies in magnetic field and received the model field pattern very close to observed. The results received shoved very high informativity of magnetic and electro-magnetic phenomena for monitoring modern lithospheric processes.

ELECTROKINETICALLY INDUCED FLUID FLOW IN POROUS MEDIA

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Can gradients of electrochemical potentials mobilise ions and induce large-scale fluid transport in rocks of low permeability? Our approach to this question is the determination of electrokinetic coupling coefficients by measurements of streaming potential, electrophoretic mobility and electro-osmosis. Surface charge density is determined. Sorption processes at solid-liquid interfaces are empirically described. We compare results from micro-electrophoresis and streaming potential measurements with observations of dipole-induced redox potential distribution in fluid-saturated quartz sediment, in which fluid flow is induced by weak electric fields. The experimental results exhibit features that are typically observed in the zonation of alteration halos surrounding porphyry copper deposits.

THE ELECTRICAL CONDUCTIVITY OF THE CRUST IN MACVA AREA (SERBIA) AND THEIR CONNECTIONS WITH TONALITE AND METAMORPHIC ROCKS

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Magnetotelluric sounding have been carried out in Mačva area during two field campaigns (1987, 1990) and their results have been used to construct distribution of conductivity in the area. These distribution shows ring like structure which have been interpreted as possible structure due plutonic body (Fisher at al, 1988). Findings of the tertiary plutonic rocks of tonalite in borehole (in the center of area) at a depth of 1335 m partly confirmed this interpretation. We study possible connections between geological and geoelectrical structure as well as petrological interpretation of conductivity distribution in the earth's crust.

Fischer G., P.-A. Schnegg and Smiljanic N., 1988: Magnetotellurics in the karst geothermal area of Mačva in Yugoslavia. - IX Workshop on electromagnetic induction in the Earth, Sochi.

STREAMING ELECTRICAL POTENTIAL IN POROUS MEDIA. THEORY AND GEOTHERMAL APPLICATION

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Streaming potentials are increasingly being observed associated with hydrothermal fields, volcanic activity, and areas subject to earthquakes. Until now a formal theoretical basis for predicting streaming potential has not been available. In this paper we develop a theory that allows the streaming potential coupling coefficient of granular porous media to be determined as a function of pore fluid salinity, temperature, water and gas saturations, mean grain diameter, and porosity. The theory has been tested against laboratory data, and has been found to provide a good explanation for the variation of streaming potential coupling coefficient with temperature, grain size, and the influence of a partial saturation of gas in the pore space. The new theory is applied to geothermal systems with geothermal convection cells. We find that the new theory provides an explanation for the presence of dipolar spontaneous potential anomalies in geothermal fields, and an explanation of the observation that the negative pole of the anomaly is usually more intense than the positive pole. This approach is also able to predict the size of the spontaneous potential from reservoir characteristics. It follows that spontaneous potential anomalies measured at the surface of an hydrothermal area appears to be a powerful way of mapping the direction of subsurface flow, and to delineate convective hydrothermal cells.

SE42 Physical properties of fault zones

Convener: Willemse, E.J.
Co-Convener: Sanderson, D.J.

Physico-Chemical Fault Sealing in Gouge Rich Experimental Fault Zones: A Preliminary Study.

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Fault Sealing may be caused by a number of mechanisms, for example; physical (e.g. Cataclasis); chemical (e.g. Cementation) and physico-chemical (e.g. Pressure-Solution). Although these processes can operate individually (as often simulated in laboratory experiments), they are more likely to operate together in nature, depending on pressure and temperature conditions in a particular geological setting.
Here, we present preliminary experimental results towards an integrated study of the role of fault zone structures (fault gouge statistics) and the ambient environmental conditions on fault sealing. Artificial fault gouges have been tested in the laboratory, both at room temperature and atmospheric pressure in standard batch tests (to calibrate pure chemical effects), and in flow experiments at pressure and temperature in artificial fault zones. Both experiments utilise size-fractionated as well as bulk mixtures of quartz-feldspar sandstone powders, from which contaminant fines have been removed using a new technique. This allows a more accurate measurement of gouge surface area and reaction rates. Rates of precipitation and dissolution are monitored by analysing for silica in the fluids for a range of realistic particle size distributions, using High Performance Liquid Chromatography. The results show a strong grain size dependence and also point to the need for more careful fines removal techniques prior to experimentation.

ELECTRICAL PROPERTIES OF DEEP FAULTS ON THE UKRAINIAN SHIELD AND ITS SLOPES.

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The used data include thousands of MTS and FDEM covering several dozens of different scale fault zones on the precambian Ukrainian shield. The preferable azimuths of conducting fault zones are 17°, 315° and less frequently 90°. The MTS curves are different for every fault azimuth, that gives ground for their identification by EM data. The crosses of the faults are the most conductive zones, they are also most penetrable for fluids and enriched by mineral deposits. Most interesting deep faults are described. Kirovograd-Kremenchug regional deep fault with azimuth 17° has near the surface the width of ~ 1.5 km and resistivity of 10-50 Ohm·m, which decreases to 1-5 Ohm·m at the depth 10 km. Ryasnopol regional structure with width 10-20 km is an example of faults with 315° azimuth. Integral longitudinal conductivity here is as high as 5 000 Sm. Devladov super-regional fault crossing all Ukrainian shield (azimuth 90°) has varying conductivity and is probably connected with Donbass electrical conductivity anomaly in the east. All the data received prove very high possibilities of EM methods in the detailed study of fault zones.

BRITTLE-DUCTILE TRANSITION IN NORMAL FAULT ZONES: IMPLICATION FOR FAULT SEALING

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Cataclastic flow and fluid interaction mostly produce fault gouge in the brittle upper crust. We have examined several normal fault zones with vertical throw ranging from one to several tens meters. These faults result from extensive tectonics that develop during or after detritic sedimentation in fluvial-deltaic environment. Lithology mainly consists of sandstone with shale intercalations which thickness ranges from several centimeters to several meters. Structural and geochemical analysis show that clay content within fault zone results from two major mechanisms: (1) drag of clay layers and (2) clay minerals crystallization by pressure-solution process. Microstructures that develop within fault gouges strongly resemble to that occurring in ductile shear zones. These microstructures include shear bands, pressure shadows around clasts, rolling structures, crack seal... This suggests that, after rupture, faults rapidly behave as ductile shear zones, where pressure solution becomes the main mechanism to accommodate deformation and displacement. Increase of both deformation intensity and clay content result in fault cross-sealing. An attempt to quantify efficiency of fault seal as a function of fault throw and lithologic components is proposed.

Structure and Physical Properties of the Nojima Fault from Active Fault Drilling

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After the 1995 Hyogoken-nanbu earthquake, we drilled a 747 m deep boreholes into the Nojima fault and conducted experiments in the borehole. The drill site is 74.6 m apart from the surface break of the fault. Cores were recovered for almost entire depth interval from 150 m to 746.6 m. The stratigraphy of the well is granodiorite from the surface. The fault zone is characterized by altered and deformed granodiorite from 426 m to 746.6 m, with fault gouge at 623.3 m to 625.1 m. The fault zone has distinctive low resistivity, density, velocities (both P and S wave; more than 50% decrease at the fault gouge), and high porosity and high Vp/Vs. The borehole observations, such as FMI logging, also revealed fine structure of the Nojima fault that corresponds to the changes in the degree of deformation within the fault zone, and the degree of deformation is more intense in the hanging wall side than in the footwall side of the Nojima fault. The width of the fault zone from the drilling result is consistent with that estimated from the trapped wave observations at the surface.

Permeability distribution in the fault zone were evaluated with very fine depth resolution from the tube wave analysis and Stoneley wave reflection, attenuation and slowness analysis. There are several permeable intervals in the fault zone, especially below the fault gouge. The fracture distribution and shear wave anisotropy show distinct changes within the fault zone.

FLUID PRESSURE IN FAULTS AND PALEOSTRESS QUANTIFICATION BY THE USE OF FLUID INCLUSION PLANES (FIP).

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Most fluid migrations in rocks are favoured by fissure permeability which forms during brittle deformation. The deformation is in some instances related to fluid pressure and movement of faults. Evidences of paleofluid migration through the fractured rock may be very scarce, whatever the observation scale, when little change occurs in the mineral assemblages resulting from fluid-rock interactions (dissolution, alteration, new cristallization). The best record of formed fluid percolation are paleofluids trapped as fluid inclusions in healed microcracks of the rock forming minerals or within the infilling of microstructures (the Fluid Inclusion Planes, FIP). However, the repeated microfracturing and healing of the rock forming minerals yield complex superimposed patterns of healed microcracks. Such patterns are often difficult to interpret due to the lack of suitable chronological criteria. These problems have been recently documented and solved by coupling deformation studies, detailed examination at all scales of the relationships between trapped fluids and their host structures, and studies of fluid inclusions. Therefore, the systematic measurements of microstructural marker orientations together with detailed fluid inclusion may results in the determination of fluid pathways and the quantification of paleostresses related to fault movements.

FAULT ZONE DYNAMICS ANALYSIS USING THE DANILOVICH METHOD

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In the northern part of Georgia there is a long-lived fault zone controlling the Valkhokhi lead-zinc deposit. The zone has been made of brought together ruptures of four orders. The hierarchy very likely reflects a succession of the structure formation. Each relatively minor rupture population has been emerged and developed under a dynamic influence of more large-scale one(s), hence the zone can be regarded as a structural paragenesis. The hanging wall of the main fault is divided by the second order faults into a number of minor tectonic blocks. Stereographic diagrams of the fourth order ruptures - fissures are characterized by a girdle-type geometry, that have been used to derive the spatial dispositions of the minor block displacement lines using the Danilovich based technique. The lines obtained as well as contemporary arrangement of rocks suggest that during common downward motion of the hanging wall its separate parts - the minor blocks moved diversely along the main fault differing in both their vertical withdrawal scale and sense of strike slip component (right- or left-handed). As a result of such displacements tectonic wedges have been formed.

DAMAGE AND FLUID FLOW AROUND NORMAL FAULTS IN MULTILAYERED SEQUENCES

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The kinematic evolution of damage zones for normal faults in multilayered sequences has been investigated using distinct element numerical modelling, UDEC. Four situations representing a fault tip, continuous fault, and dilational and contractional jogs have been modelled. The evolution of a series of geometrical and mechanical features (fault slip, block rotation, lateral deformation, fracture aperture, damage distribution, and flow-rate) are compared quantitatively. Also, the stress distribution and resulting damage are analyzed, which provides some explanation of how damage zones are related to different fault geometries and stress states.
The main conclusions from the models are: 1) Considerable localization of the opening of fractures, and associate fluid flow, results from fault movement, particularly at fault tips and in association with jogs. 2) The geometry of the fault segments and jogs determines the general pattern of damage, with distributed damage zones at fault tips and contractional jogs, but more localized damage at pull-aparts and dilational jogs. 3) Fluid flow is highly localized within the damage zone. These features, predicted from the models, are compared with field examples from Kilve, Somerset, and elsewhere.

The prediction of fault damage zone structures using strain derived from kinematic modelling at a potential radioactive waste repository.

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A range of algorithms is available to apply brittle and ductile deformation due to faulting and folding to 3D geological models. The change in shape of the hangingwall is used to derive strain during structural restoration. Using efficient, non-elastic algorithms, detailed/localised strain fields can be derived to predict the nature of internal structures and extents of fault damage zones. The process of 3D restoration and derivation of strain has been conducted for a model (2.5km x 2.5km x 1.5km) of a Potential Repository Zone (PRZ), at Longlands Farm near Sellafield in West Cumbria, UK. This model was constructed as part of a Site Characterisation programme conducted by Nirex to investigate whether the site could be suitable for the deep geological disposal of intermediate and low level radioactive waste. Strain data derived from restoration of faults at a 100m scale, correlated favourably with the deformation associated with faults seen in boreholes (<1m scale) and cross hole seismic tomography (5-15m scale). The correlation implies that the smaller faults are part of a damage zone developed by the larger fault. This in turn allows the nature of the internal damage zone to be predicted away from borehole control.

QUASI-STATIC MECHANICAL PROPERTIES OF FAULTS

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Fault zones cause dramatic discontinuous changes in mechanical and transport properties over short distances, and form long-lived networks of weakness in the lithosphere. To obtain more detail in Byerlee's law at low pressures, we conducted a literature survey focusing on the mechanical properties of fault gouges in sand-clay sequences at depths up to 4 km, during slow-non seismic deformation. The faults considered are "mature" faults uneffected by diagenetic strength recovery, with a slip of more than 1 meter, when a true steady state shear strength is is reached. Most of the data come from ring shear tests. Because cohesion is destroyed by fault movement, strength drop in a fault is a strong function of the cohesion of the country rock. Thus the most important parameter to characterise mechanical properties in this state is the residual friction angle Fr, which in turn is controlled mainly by clay content and clay mineralogy of the fault gouge.The residual friction angle can be as low as 5 degrees for pure montmorillonite with a very high surface area, up to 35 degrees for sand-rich gouge. Fr is a weak function of the illite and kaolinite fraction, and the chemistry of the pore fluid. Only the residual friction angle of montmorillonite shows a significant pressure dependence. Dilatancy angle in mature fault gouges is zero. The more granular gouges (e.g. kaolonite-rich) show a turbulent mode of deformation whereas the weak platy ones deform in a sliding mode. Inversion of fault-slip data and field observations of landslides field observations are in reasonable agreement with laboratory data, indicating that the residual friction angle is not strongly rate-dependent and elastoplastic constitutive behaviour is a good approximation of the mechanical properties of non-seismic faults in the upper crust

THE INFLUENCE ON FAULT PROPAGATION OF STRESS SYSTEM AND LAYERING

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A range of fault propagation styles are described, from the vein-dominated propagation of normal faults, through the shear fracture dominated propagation of strike-slip faults, to the pressure solution seam-dominated development of transpressional shear zones. These structures reflect extension, approximate simple shear, and transpression respectively, and an annulus model is used to illustrate the systematic change in fault propagation style as the stress system varies. The relationship between stresses and layering also has a strong influence on the propagation style, with strike-slip faults in vertical beds propagating in a similar way to normal faults in horizontal beds. Fault propagation at the metre-scale is mainly by the linkage of extension fractures or pressure solution seams, while propagation at large scales is dominated by the linkage of fault segments. Factors effecting the style of fault propagation therefore include the stress system and layering, with lithology and pre-existing fractures also being important.

NORMAL STRESS CONTROL ON CATACLASTIC ZONE DEVELOPMENT AROUND NEO-RUPTURED FAULTS

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Experimental rupture of sandstone samples under shear stress was undertaken for a range of normal stresses from 15MPa to 87MPa. Rupture was found to be instantaneous to the naked eye for the lowest normal stress, descreasing in brutality with increasing normal stress. The rupture surface, never planar, was defined in every case by surfaces gently dipping in the opposite sense to the opposite block movement direction, linked to Riedel surfaces (dipping towards opposite block movement) whose dip increases with increasing normal stress. These Riedel faults continue into the wall rock as narrow cataclastic zones of variable grain size reduction. The following Riedel fault properties increase with increasing normal stress: 1) Their average dip from the rupture surface (10° to 60°). 2) Their frequency. 3) Their connectivity. 4) Their thicknesses. 5) Their penetration into the wall rock. 6) Degree of bimodality in orientation (higher normal stress examples have cataclastic zone geometries consistent with Sibson's mesh model configuration linking en échelon fault segments across a dilational jog). In summary, lower rupture brutality yet far greater cataclastic damage intensity and penetration around the rupture zone occurs with increasing normal stress.

SE43 Advances in the physical interpretation of electromagnetic soundings

Convener: Marquis, G.
Co-Convener: Perrier, F.

SOLVING OF THE INVERSE PROBLEM FOR DEEP ELECTRICAL SOUNDINGS IN THE REGION OF LAKE BAIKAL, RUSSIA

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More than 200 deep Schlumberger soundings (transmitting dipole was as much as 16 km long) were used to solve the inverse problem within the Selenga River Delta (Lake Baikal). State enterprise IRKUTSKGEOFIZIKA obtained the data the early fifties. Geophysical information system SONET-MAP 1.0 was implemented for data processing and inversion. On the basis of 2D mathematical modelling the basic types of sounding curve distortions have been revealed and analyzed. Consider tion was given to the practicality of 1D models. Drilling information was used to constrain inversion and thus to obtain reliable estimates of sediment resistivity. Three types of distortions have been discovered. Geological considerations allowed to propose the most simple 3D models which can clarify the distortion patterns. Distortion of D type can be described in the context of a model " horizontal highresistivity inhomogeneity in a halfspace". Distortion of U type is a accompaniment of the model "step-fault in a resistive basement"(center of survey line locates above the descending wing). The ascending flank of the model is responsible for the slope of the curve greater than 45 degrees. The preceding model also governs the shape of the curve with distortion of B type (center of survey line locates above the up-tending flank).. The map of basement surface includes the information about seismic events occurred within the region in a time 1984 - 1990. As the data suggest, several epicenters of strong earthquakes (energy class K > 9.6) locates in an arc near the west upli ted block of the basement. This block was originally discovered during the presented research. The arc received the name
Tvorogovskaya seismogeneous arc.

TELLURIC ANALYSIS OF DISTRIBUTED MAGNETOTELLURIC IMPEDANCE MEASUREMENTS

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The normal method of analysis of magnetotelluric impedance tensors treats each site separately. A model of the conductivity is assumed, for instance local heterogeneities causing galvanic distortion of the electric fields associated with a regional-scale one- or two-dimensional structure. The tensor can then be decomposed to yield information on the regional strike and local distortion. When it is rotated into the regional strike coordinates, elements in the same column share the same (regional) phase. These elements can be regarded as the electric fields produced by a magnetic field either parallel or perpendicular to the regional strike. If a group of MT sites share the same regional response, though experiencing different distortions, the rotated electric fields plot on a line of constant phase in the complex plane, and this can be used as a criterion for determining the strike. Maps of the simulated electric field can be used to assess both local and regional scale structure. This approach is applied to data from the Kayabe geothermal area in Japan.

NEW APPROACH IN 3D VLF-EM DATA REPRESENTATION: EXACT LOCATION OF CAVITIES IN KARST FORMATIONS FROM FIELD SURVEY

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In the aim to improve the safe operation and economy of a french limestone quarry site located in karst formations, VLF-EM survey has been involved to detect and locate cavities anomalies. The 100 ha investigation zone has been sampled using 10 m step profiles irregularly distributed at the surface Spatial filtering has allowed to reconstruct the third dimension in depth. Both real and imaginary data components has been processed to point out the heterogeneity degree of the encountered anomalies. Interpolation process has been achieved to investigate the whole zone from the 2D irregularly distributed profiles. Moreover, the results of the already done drilling have been correlated with the VLF-EM analysis to determine the depth and the equivalent thickness of the economically exploited geological level (good, weak or poor). Three main conclusions can be extracted from this VLF-EM experiment survey. (1) The strongest detected 3D anomalies exactly correspond to already known totally empty caves encountered by the quarry operators. (2) Processing both the real and imaginary data components leads to discriminate the already empty cave from the favourable dissolution zone. By the way, the initial goals (safety and economy aspects) are reached. (3) Recent developments in 3D processing provide 3D representation to exactly locate the anomalies and the equivalent thickness of the economically exploited reef.

ANISOTROPIC AND DIMENSIONAL CHARACTER OF MT RESULTS FROM SOUTHERN PORTUGAL USING MOHR CIRCLE ANALYSIS

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Magnetotelluric (MT) measurements have been made at 34 sites in southern Portugal in the area of the intersection of the Messejana fault and Ferreira-Ficalho overthrust. A 2D data acquisition strategy was used so that the interpretation is not restricted to 2D models and 3D characteristics can be investigated. Maps of electrical resistivity at several depths constructed from 1D models for the 34 sites show a complex geoelectrical structure of resistive blocks that extend to great depths and which are separated by low resistivity zones that coincide with the fault and overthrust. Both 2D and 3D numerical models have been constructed for the area and results from these models have been compared with the field results. Mohr circles have been plotted from the MT impedance tensors for the 34 sites for 5 periods. Contour plots of parameters from the Mohr circle calculations show distinct differences between the geologically complex Ossa-Morena zone to the north and the South-Portuguese zone to the south. Both anisotropy and skewness are more variable and generally greater in the Ossa-Morena zone. Furthermore, these parameters show considerable variation with period in their spatial character, indicating that both the anisotropy and dimensionalities of the structures vary with depth.

3D CONDUCTIVITY STRUCTURE OF A PLIO-QUATERNARY TECTONIC BASIN: THE VILARIÇA BASIN (NE PORTUGAL)

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The Vilariça basin, located northeast Portugal astride a major late-Variscan NNE-SSW reactivated strike-slip fault, is an excellent example of interplate neotectonic activity. Fifteen magnetotelluric soundings were carried out northern of the tectonic basin with the objective to investigate the internal structure of the basin and its relationship with the main tectonic accidents. The magnetotelluric data were acquired in four frequency bands, from 180 to 1/125 Hz. An analysis of the impedance tensors, using the Groom-Bailey decomposition technique, allow to distinguish two main regional strikes of N20E and N50-58E. Using three-dimensional approach a model for the studied region was constructed. The model evidences conductive zones related to sedimentary filling and an increasing of the resistivity at depths greater than 2 km, associated with the Hesperian basement rocks.

PROCESSING OF NOISY MAGNETOTELLURIC DATA WITH THE TWO SOURCE METHOD: AN EXAMPLE FROM THE SAXONIAN GRANULITE MASSIF

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With the continuous advance of human beings and technology into all parts of Europe, it is becoming more difficult to get non-biased magnetotelluric (MT) and magnetic transfer functions from the recorded variations of electromageic fields. In the year 1995, time series recorded along a profile in the Saxonian Granulite Massif are contaminated by strong correlated noise signals, and robust single-site estimates of transfer functions give erroneous results. By using a smoothly varying transfer function, which facilitates identification and removal of electric and magnetic outliers, and by simultanously estimating MT and cultural noise transfer functions (Two Source Method), we succeeded in separating the time series into MT signal and correlated noise signal.

The Two Source Method requires a noise-free magnetic remote site. For this, stations from a simultanous MT campaign in the Odenwald (distance 350 km) were available. One station has an extremely low noise level and it proved to be an ideal remote station. We also tested other remote stations, consulted additional electric remote sites and compared the results.

ELECTROMAGNETIC INVESTIGATIONS OF DYNAMICS OF TECHNOGENIC PROCESSES IN MINE FIELDS AND IN HYDRAULIC ENGINEERING WORKS

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The problem of studying the dynamics of technogenic carst and physical-mechanical state of ground dams, tailing dams and hydroelectric station dams is very urgent together with carstological and other processes resulting in the above-mentioned structures gradually loosing their steadiness and leading to disastrous consequencies. Among the most efficient means of solving these problems is a complex of electromagnetic investigations by methods of impulse and frequency soundings which besides field observations include mathematical and physical modelling. The latter is used both at the stage of choosing methods for observations and in the process of interpretation of data obtained. Physical-geological basis for electromagnetic methods is considerable differencies of specific resistance between tight and shaken-up rocks and soil. Particular examples of successful studying carstic danger in mine fields and steadiness both of tailing dams of precarpathian pits and the dam of Kyyiv Hydro are given. Promising informativity and prognostic possibilities of methods used are presented. This is confirmed by further formation of dips and zones lacking in tightness within dangerous sections found.

NEW PROCESSING FOR MAGNETOTELLURIC REMOTE REFERENCE OBSERVATIONS

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Robust estimates of magnetotelluric and geomagnetic response functions are determined using the coherency and expected uniformity of the magnetic source field as quality criteria. The proposed criteria cause data rejection based on two aspects: (i) if horizontal magnetic field components between two sites have low coherencies (coherency criterion) and (ii) if the response functions are considerably different from unity (target criterion). Time segments with inconsistent horizontal magnetic field data are thereby removed, leaving a reduced but cleaned data set for the final robust stacking. The method is applied to data sets of three simultaneously recorded sites. The processing results show that the amount of noise on the horizontal components of the magnetic field varies considerably in time, between sites and over the frequency range. The removal of such contaminated data beforehand is essential for most data processing schemes, as the magnetic channels are usually assumed to be free of noise. The standard remote reference method is aimed at reducing bias in response function estimates. However, this does not necessarily improve their precision. With our method, we can filter out source field irregularities, thereby providing suitable working conditions for the robust algorithm, and eventually obtain considerably improved results.

CONDITIONS PROVIDING THE EFFECTIVE USING OF THE APPARENT RESISTIVITY FOR THE MT-MONITORING OF THE GEODYNAMICAL PROCESSES

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Using numerical modelling there is studied the sensitivity of the MT apparent resistivity to the variations of resistivity ρ_i of some element of the 1-D structure. There is shown that in many cases this sensitivity is very high: the relative variations of ρ_a can several times exeed the corresponding relative variation of ρ_i. On account of that ρ_a can be effectively used, under determined conditions, for monitoring purposes. In case of two-layered structure the best conditions for studying variations of conductivity are (I) for the underlaying layer: small difference between ρ_1 and ρ_2, small thickness of the upper layer d_1, the maximal possible EM wave period; (II) for the upper layer: $5.3 < \lambda_1/d_1 < 8.4\sqrt{\rho_2/\rho_1}$. In case of three-four layerd structure it should be pointed out the following: (I) the most high sensitivity takes place in case of conductivity variations of the high-cunductive layer; (II) the presence of the high-conductive layer makes it difficult to study the conductivity variations of the less conductive layer.

THE METHOD OF CALCULATING THE IMPULSE ELECTROMAGNETIC FIELD OVER ARBITRARY GEOELECTRIC SECTIONS

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Impulse Electromegnetic methods are widely used nowadays to solve numerous structural, prospecting and engineering-geological problems. But their mathematical substantiation is restricted to 1D horizontally layered and asymmetric sections or inclusions of regular form in a half-space. Therefore, elaboration of methods for determining non-stationary electromagnetic fields in complex, close to real sections is of paramount interest. The method of boundary elements comparatively easily modelling arbitrary including curvilinear inverfaces of layers and inclusions with permanent electric characteristics seems to be suitable for this purpose. Taking into account impulse character of field generation the system of maxwell's equations is reduced to parabolic and hyperbolic equations for the conducting medium and an upper insulator (air), respectively. To solve the bounbary problem interfaces are divided into boundary elements with fictitious current sources of power determined using the collocation methods and methods of stepwise change of time. Numerical examples confirm expediency and efficiency of boundary element techniques in determining impulse electromagnetic fields in complex geoelectric sections both for choosing rational systems of field observation and more reliable interpretation of data obtained.

USE OF NON-CONVENTIONAL APPROACH IN MAGNETOTELLURICS

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In this paper - by using several examples based on the activity of the authors - it will be illustrated that non-conventional physical approaches may largely increase the possibility of the magnetotelluric method. The examples are related to two magnetotelluric problems. (1) The interpretation of the skindepth as "penetration depth" is correct only for infinitely deep homogeneous halfspaces. The situation will be dramatically changed due to the presence of a layer boundary, or even due to any inhomogeneity of finite lateral extension. This observation oriented us to study the short-period section of the sounding curve, where, in some situations, exceptionally good 3D images can be obtained. (The description of the so called "keyhole imaging" is given by Szarka and Menvielle, 1998, submitted to Geophysical Prospecting, based on paper F007 at the Geneva EAGE Meeting.) (2) The traditional MT apparent resistivity definition is not the best one even in 1D situations. With the advent of 3D measurements and interpretation techniques, in order to avoid a further accumulation of this problem, we suggest to revise the definition of magnetotelluric apparent resistivity. We have found that the rotational invariants of the real tensor (the elements of which are the real parts of the 2x2 complex elements of the magnetotelluric impedance tensor) are the best parameters in a wide period range (For the rotational invariants see Szarka and Menvielle, 1997, Geophysical Journal International, 129, 133-142.)

COMPARISON OF TENSOR DECOMPOSITION METHODS ON MT DATA MEASURED IN THE PANNONIAN BASIN

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In the Pannonian basin, two-dimensional (2D) structures are expected in the regional scale. This hypothesis is based both on the zonal structure in geological maps of the depth of the Pannonian basin and on 2D anisotropy, seen in magnetotelluric results. Effects of possible near-surface three-dimensional inhomogeneities were investigated on wide-period magnetotelluric soundings by using different tensor decomposition methods, suggested for such a model: among others the Groom-Baily technique, the Bahr-decomposition and the eigenvalue techniques were used. According to the present experiences, the different techniques may give very different solutions for the regional 2D structures and they not always seem better in comparison to the pre-decomposition results. In the paper we try to investigate the physical meaning of different approaches in such a geological situation

INVESTIGATION OF THE MAGNETOTELLURIC TENSOR INVARIANTS AND THEIR PHYSICAL INTERPRETATION USING A SYNTHETIC MODEL

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We have characterized the magnetotelluric (MT) tensor by seven invariants which differ somewhat from those proposed in a recent paper by Szarka & Menvielle (Geophys. J. Int. **129**, 133, 1997) and have given a physical interpretation for the vanishing of each one. The seventh invariant is associated with the presence of a three-dimensional (3D) geo-electric structure in the region and is closely related to the "phase sensitive skew" of Bahr (J. Geophys., **62**, 119, 1988). Its vanishing is indicative of small-scale, near-surface distortions of a regionally 2D MT field. In order to test the physical interpretation of each invariant we have constructed a 3D numerical model comprising a 2D fault line plus a small conductive anomaly in the shape of a square plate near the fault. The regional field is taken to be inclined at an angle of 40° to the fault. The complex elements of the MT tensor have been computed at various points in the model, both where the influence of the anomaly is felt and where it is negligible, and the various invariants have been evaluated. The physical interpretations of the invariants have been verified for this simple model and the direction of the strike of the fault line has been recovered with acceptable accuracy. It is hoped that the proposed invariants may shed useful light on the geo-electric character of a region under investigation in real cases.

THE FALSE CONDACTIVE ANOMALIES ON 1-D INTERPRETATION AND EXEPTION THEM BY FOLLOWING 2-D INTERPRETATION

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On the 1-D interpretation of the MT-data in case of strong horizontal inhomogeneous medium it is possible the appearance of the false condactive zones at a depth of 30 – 100 km. However the 1-D interpretation results on the profile can be use as a start model for the 2-D interpretation. The false condactive zones disapea on the 2-D interpretation by E-polarization and stay by H-polarization. Combined 2-D interpretation of E-and H-polarizations allows also correctly determine the limits of the true conductive zone. These conclusions have been drawn by numerical modelling. The parameters one of taken models are: in homogeneous medium with resistivity 100 $Om \times m$ is 2-D conductive including $0.3 \times 2\ km^2$ with resistivity 0.5 $Om \times m$.

AMT SOUNDINGS IN SPESSART MOUNTAINS

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Within the framework of audiomagnetotelluric measurements in the Spessart mountains (Germany) magnetic and telluric time variations in the frequency range from $0.001s$ up to $1000s$ were observed. The time series were severely disturbed, however, by noise from cultural and industrial sources.
Two different methods were applied in order to diminish these influences:

1. Shielded cables suppress the influence of high frequency noise acting as lowpass filters. They were replaced by RC-coupled elements connected to unshielded cables in order to get a similar lowpass filter. Different setups are compared by field and laboratory studies, generally improving the data quality.
2. An additional improvement was achieved applying the remote refenece technique to simultaneous time series recorded over distances between $1km$ and $100km$.

SE44 Can electromagnetic images constrain geophysical interpretation of tectonically active environments?

Convener: Simpson, F.
Co-Conveners: Manzella, A.; Ritter, P.

ON THE ORIGIN OF MECHANOELECTRICAL EFFECT BEFORE AN EARTHQUAKE

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In order to clarify action of the strain on the resistivity we present quantitative description of electrical properties and their changing by action of external forces based on the theory of heterogeneous and disordered sytems. The conductivity of two-phase rocks in the critical stage when the volume part of the strongly conductive part is very close to the percolation threshold was considered. The strain sensitivity. i.e. difference quotient of the resistivity to the length. is expressed as a function of a volume part of conductive component, effective conductivity. compressibilities of the phases etc. An assumption that the conductivity has percolation character explains anomalous changing the strain sensitivity before and during an earthquake. Various threshold values of strain sensitivity are predicted as functions of the sizes of both the conductive and dielectric parts.

ELECTRICAL ANISOTROPY AND EUROPEAN STRESS

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Electromagnetic data from the Rhenohercynian and Saxothuringian in southern Germany (ERCEUGT, 1992) have been re-examinated in conjunction with actually measured field data. A possible explanation for both phase differences between the two principal magnetotelluric polarisations and strong vertical magnetic fields is an electrically anisotropic structure in the middle crust with maximal conductance in SW-NE direction. This conductance has a gradient in NW-SE direction which is responsible for the occurence of a vertical magnetic field. The NW-SE direction of the minimal conductance coincides with the direction of maximal stress in central Europe (Brereton and Müller, 1991). The view that the present stress field controls electrical anisotropy via the distribution of microcracks (Bahr 1997) is supported by observations from Northern Germany and Finland. In the KTB location "Zone Erbendorf- Vohenstrauss" (ZEV), however, the situation is reversed: the WSW-ENE direction of minimal electrical conductance (ELEKTB group 1997) follows a paleostress field from 300 Ma, when the ZEV was uplifted. Implications for the conduction mechanism at the different test areas are discussed.

PRELIMINARY EM INVESTIGATIONS OF THE SEIMO-ACTIVE REGION OF NORTHERN BOHEMIA

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During 1997, in the frame of an Italian-funded scientific cooperation between Italy and Czech Rep., a series of MT and MV soundings were realized in the region of Northern Bohemia. This area is one of the most seismo-active regions in Central Europe due to the relatively frequent occurence of micro-earthquake swarms which take place even during each apparent quiescient interval between two large macro-seismically observed swarms. 15 MT and 2 MV stations were istalled in an area of around 15×20 km^2 where about 80% of seismicity of the whole region was recorded since 1986. The area showed a high electromagnetic noise which affected both electric and magnetic recorded signals. Nevertheless a preliminary analysis of the data showed geoelectric features which will be discussed from the point of view of the seismic characteristics of the region.

GEOELECTRICAL ANOMALIES AND THEIR RELEVANCE TO TECTONIC INTERPRETATIONS

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Geological investigations in the Continental Deep Drilling (Germany) have revealed that graphitic shear zones are an important marker for tectonic events. These ore mineralizations form large bodies of interconnected electric conducting material. Since standard conductivity measurements can not distinguish between electrolytic and electric conductivity mechanisms, additional methods have to be introduced. According to the concept of the geobattery, contineously mineralized shear zones may be discovered by monitoring self-potential (SP) anomalies. Another possibility to detect such zones is the application of the nonlinear induced polarisation (NLIP) method,which takes advantage of nonlinear current-voltage-characteristics observed by using a standard IP-configuration. Extensive field experiments were carried out at a drill-hole near Rittsteig (Germany). SP anomalies as well as subsequently performed geological investigations reveal graphitic shear zones. In order to quantify the NLIP effect, an alternating current was injected in the drillhole. Simultaneously the electric potential was measured on the earth's surface. The NLIP was observed and an interconnected electric conducting layer - obviously a shear zone containing graphite - steeply inclined in south direction was indicated. Therefore SP and NLIP surveys seem to be a powerful method to detect interconnected mineralized shear zones and thus provide important information for structural geology.

THE RESISTIVITY STRUCTURE OF THE ACTIVE CONTINENTAL MARGIN IN NORTHERN CHILE

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A set of broadband (10^4 - 10^{-4} Hz) magnetotelluric data was collected in the forearc and arc region of Northern Chile. Decomposition of the magnetotelluric transfer functions suggests that 2D modelling of the data is possible. The forearc appears extremely resistive. The existence of a continuous conductor on top of the subducting Nazca Plate, as observed by Kurtz (1990) for the Juan de Fuca System, can probably be excluded. The dominant structure in the model is a subvertical conductive block that reaches from 10 km to great depths. This structure is situated approximately 20 km west of the active volcanic arc. It may correspond to the Falla Oeste, a deep reaching fault system in the Chilean Precordillera, which probably provides a pathway for the rise of metamorphic fluids from the downgoing slab. The magmatic arc itself seems to be a poor conductor - consistent with a lack of recent volcanism in the area.

ADDRESSING GEOLOGICAL NON-UNIQUENESS IN APPRAISING TECTONIC CONSTRAINTS PROVIDED BY EM DATA

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Interpreting electromagnetic data in terms of tectonic process requires the recognizition and resolution of two non-uniqueness problems. The initial problem is to understand the range of models that can satisfy the data. This problem is well studied. However, translating inverted models into geological understanding requires understanding the non-unique relationship between tectonic setting and electrical physical properties. In this talk I review the two stages of problems involved with interpretation. An example of magnetotelluric data from Western Canada will serve to illustrate methods of controlling model non-uniqueness and to show how the deleterious effects of geological non-uniqueness can be mitigated. Only by dealing with these two forms of ambiguity can concrete and identifiable constraints on tectonic interpretations be provided by the geophysical data.

THE STOCHASTIC MODEL OF ELECTROKINETIC-MAGNETIC EFFECT FOR QUASIHOMOGENOUS MEDIUM.

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It is well known that the magnetic effect caused by electrokinetical processes on the surface of homogenous halfspace is absent. However, taking into account that the real geological medium, when there are absent macroinhomogeneities, is but quasihomogenous, we consider the statistical features of electrokinetic-magnetic effect on the surface of such a medium by the help of Monte-Carlo methode. Our model is based on the effect of surface conductivity influence on the rock conductivity for microcapillar racks (d<50 μm). The obtained results are as follows.1) The magnetic effect as a rule is present. 2) The distribution of magnetic field changes as a result of random changes of microcapillars structure in case of constant value of the microcapillars space distribution dispersion is similar to the distribution of magnetic field in static case. The main feature of these distributions is symetry of positive and negative values of effect. 3) In the case of nonconstant value of microcapillars space distribution dispersion the main feature of the distribution of magnetic field changes is asymetry of positive and negative values of effect. The first two results may be useful for the evaluation of natural magnetic noise when monitoring active faults by geomagnetic methodes. The third result we consider as a useful link for the magnetic image of tectonically active environments evolution constraining.

ABOUT POSSIBILITIES OF STUDYING TECTONIC ACTIVITY OF FAULTS USING TECTONOMAGNETIC INVESTIGATIONS

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Tectonic faults of lithosphere are known to represent fractured zones permeable for fluids, where, as a rule, different strain processes are far more intensive compared with those beyond their boundaries. The study and mapping of these zones are necessary to investigate into modern geodynamics and seismotectonics of separate regions, as well as are of applied significance at prospecting of mineral resources.
Studying temporal changes of anomalous magnetic field is due to tectonomagnetic method based on repeat high-accurate observations at a special network of points. Differential observation methods which eliminate field changes of global and external (ionospheric) origin are used. These methods make it possible to obtain data about anomalous changes of geomagnetic field caused by tectonic processes.
The following mechanisms may be sources of anomalous changes in a fractured zone: piezomagnetic effect - changes of magnetic properties of rocks under influence of variable tectonic stresses, and electrokinetic phenomena caused by electric currents generated due to relative phase motion (liquid-solid) under influence of variable pressure. It is possible to detect active tectonic faults in different regions (Carpathians, Northern Caucasus, Dniprovsko-Donetska Trough) due to positive application results obtained. Anomalous effects in fault zones reach 2-5 nT, and are detected effectively at accuracy of repeat geomagnetic observations ±0.5-0.8 nT.

ELECTRICAL STRUCTURE FROM THE GANGETIC PLAIN TO THE HIMALAYAS

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We present here a preliminary analysis of magnetotelluric (MT) data acquired across Central Nepal to study the conductivity structure of the crust and upper mantle of the active Himalayan region. We have estimated the MT impedance by a robust method (Chave et al., J. Geophys. Res. 92, 633, 1987) for frequencies between 0.001 to 500 Hz and have acquired DC Schlumberger soundings at most sites to correct for static shifts. In the north, the electric field is also distorted by the rugged topography and by near-surface accidents. We have decomposed the MT tensor using the method of Counil et al. (Ann. Geophys. 4, 115, 1985) to minimise the effects of this distorsion. Our data show that Central Nepal's present-day geoelectrical structure is of growing complexity from south to north. The study of distorsions and the induction vectors confirm this observation and indicate that the northern segment of the Main Central Thrust is associated to a major conducting feature. We can link this result to stronger hydrothermal activity or to the presence of graphite. We have also acquired a short Audio MT profile just south of the Main Frontal Thrust along the Bakeya River. It shows a very strong conductor which geometry suggests that recent deformation has occurred. We will also present the results of 2D and 3D modelling currently in progress.

AUDIOMAGNETOTELLURIC SOUNDINGS ON THE MONTECRISTO ISLAND (ITALY)

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In 1997, a joint research project which involved Italian and German institutes was conducted within the activities of GEOSTAR. Magnetic and (audio-)-magnetotelluric measurements were performed on and around Montecristo Island (between Tuscany and Corsica) by using ground-based and sea bottom sensors. It was the primary research objective to develop a quantitative model of the electrical conductivity distribution beneath the Tyrrhenian Sea at the westerly extent of the Tuscan geothermal anomaly.
SACLANTCEN deployed ocean bottom magnetometers in the vicinity of Montecristo Island and collected simultaneous oceanographic data. The Göttingen group set up tree long period magnetotelluric systems (measuring periods > 10 s). The Frankfurt group made audiomagnetotelluric measurements in the 0.1 - 128 Hz frequency band at four sites along a radial line from the island centre to its shore, recording data always at two sites simultaneously.
First AMT results will be presented which lead to the construction of a conductivity model of Montecristo Island.

MT SURVEY IN THE AMIATA VOLCANIC AREA: A COMBINED METHODOLOGY FOR DEFINING SHALLOW AND DEEP STRUCTURES

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In 1994-1995 a magnetotelluric (MT) survey was carried out in an area sited on the western edge of the Amiata geothermal region (Tuscany, Italy). A combined data recording methodology was used, in an attempt at enhancing the resolution of subsurface conductivity along the survey line, defining the deep features related to geothermal system recharge, and tackling the problem of high noise level in the area. Standard wide-band MT data (100-0.01 Hx) were collected at 28 sites, and 130 high frequency (100-1 Hz) telluric-magnetotelluric (TMT) soundings were carried out at sites adjacent to the main wide-band sites.
Two-dimensional inversion modeling of both TM and TM-TE data was performed, taking into account topographic and coast effects. The modeling results defined both the shallow and deep resistivity anomalies. The structural significance of these anomalies is in good agreement with structural information derived from other geophysical data.
Of particular geothermal interest is the evidence of a large conductive anomaly at a depth ranging between 2 and 4 km, within the deep metamorphic basement. This anomaly could indicate the presence of a hitherto unidentified deep reservoir that is in comunication with the reservoir exploited at present in the Amiata area.

MAGNETOTELLURIC PROFILES IN SOUTHERN APENNINES

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The complex geometry and kinematics of the fold and thrust belt of the Southern Apennines is still matter of debate.Seismic data of the deep structures in the western part of the chain do not conform enough to models which can be illustrated by a regional cross sections of Southern Italy. We find that magnetotelluric method can help to better define the regional structural set up and give some new physical insight on rock properties. Magnetotelluric soundings were carried out along two perpendicular profiles. The main NE-SW regional profile crosses all the most important tettonic structures of Southern Apennines. A decomposition of the impedance tensors using Groom-Baley's scheme shows that a two-dimensional interpretation is possible. We realized thus a two-dimensional model. The model pointed out two main tectonic domains: eastwards, the resistive Apulia carbonate platform shows almost flat horizons, while, westwards, the conductive Apenninic chain shows a more complicate electrical behaviour. Large carbonate bodies beneath the outcropping tectonic units are recognizable in this area. We performed also a correlation with other geophysical and geochemical data. The geological interpretation which can be depicted from this set of magnetotelluric data is remarkably similar to recent alternative models proposed for Southern Apennines which indicate large carbonate structures beneath the shallow carbonate and basinal units cropping out in the Campania-Lucania region. This tectonic setting implies different restoration and forward modeling of the structures on a regional cross section.

EXPLICIT EQUATION 3-D TIMEDEPEND ELECTROMAGNETICS INVERSION.

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We have obtained the new inverse problem equations of timedepend electromagnetic fields. There are the first generation equations with explicit operators. The primary field source can be arbitrary type, EM fields satisfy diffusion and Helmholtz equations. We have used representations of field functions through the values of the functions themselves and the derivatives at the boundary of the anomaly-forming object. The method for solving of 3-D nonlinear electromagnetic inverse problem was diviced. It is based on the algorithm for solving explicit equations of the 3-D inverse problem . The algorithm was successfully tested on a number of model examples. We apply the Tikhonov regularization method to 3-D EMD inversion. We do EM data inversion by two-stage interpretation method: 1) approximation of the observed data with the fields of singular sources; 2) construction of equivalent objects with different physical parameters values. As a result of interpretation we obtain the bodies stellate relative to some point with different values of conductivity (permeability) which generated the same (electrical or magnetic) field. We have studied the possibilities for solution uniqueness. We have some examples with good results of interpretation.

ELECTROMAGNETIC TOMOGRAPHIC IMAGE OF 3D GEOLOGICAL MEDIUM WITH USE OF TEM DATA

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The EM image of a geological medium is, in basic, distribution of electrical conductivity. The conductivity of a medium well shows a structure of a medium and its modifications. The interpretation of EM measurements is the difficult task, if a medium complicated (2D, 3D). We develop the approach, in which we make the following:
(1) we divide a medium on a set of the standard elements; (2) we select a background medium (one-dimensional or homogeneous); (3) we construct nearby of this simple medium the approximate 3D forward problem, which is linearized for perturbations of conductivity from the background medium; (4) we make inversion of data, as inversion of a linear system, which connects experimental data and perturbations of conductivity; (5) we restore a structure of a medium by an image of found distributions of conductivity. Our approach is possible to determine, how diffraction tomography in a Born approximation.
Here we demonstrate our approach with use areal synthetic TEM data. The synthetic data are obtained by the independent 3D simulation. Model of a medium - homogeneous half-space, containing a heterogeneity. The inversion is produced in some iterations. At the first stage a rough and extensive tomographic partition of medium is used and we obtain a fuzzy image. However, now we can localize and condense the tomographic 3D grid nearby of the target.

EXTREMELY LOW FREQUENCY MONITORING OF TECTONIC ACTIVITY

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An extremely low frequency (ELF) transmitter located in Kola peninsula is used for ELF monitoring of tectonic activity. It consists of a harmonic current generator and a 60 km length horizontally located antenna. The value of a current in the antenna reaches 300 A. The operating frequency range is 30-200 Hz. A valid operation distance is up to 10 000 km. Measurements of harmonically varying fields using signal accumulation permit to ensure a high noise immunity and accuracy. In a distant zone the normal field of the source can be approximated as a plane wave, that enables to execute authentic interpretation of results. The use of extremely low frequencies provides rather large depth penetration of a research, at which an influence of interfering seasonal factors is practically eliminated. An ACF receiving hardware-software complex, technique of measurement and processing software has been developed for the ELF monitoring. Experimental investigations on Northern Caucasus and near St. Petersburg were carried out. It was shown, there was a possibility to measure the ELF transmitter signals with frequency resolution of 0.007 Hz and to register a small impedance changes (4-6 %) during a day, which were correlating with earth crust deformations due to tide phenomena. The measurements of natural electromagnetic fields in these experiments permitted to obtain a lower (3-5 times) accuracy, which depends on time of the day in addition. The work has been carried out under «Integration» grant, project № 326.66.

3D MODELLING STUDIES OF THE CONNECTION BETWEEN MAGNETIC DISTORTION EFFECTS IN GDS DATA AND THE SCALE LENGTH OF CONDUCTIVITY ANOMALIES

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The magnetic response of a confined structure depends on its scale length, its depth, its dimension and its conductivity contrast with respect to the host material. These parameters determine the period range in which the anomalous magnetic fields are generated by currents induced inside the anomaly. At longer periods, the response is produced increasingly by currents that are only concentrated close to and inside the body, but induced in the host material. The 3D modelling studies show that these two processes can be distinguished by examining the phase of the magnetic response function. It changes from negative values in the period range of local induction to positive values approaching the regional impedance phase in the range where current deviation is the predominant process. The magnetic fields created by the latter process may cause a misleading interpretation of induction arrows especially in terms of regional strike directions. A detailed study of anomalies of different sizes and conductivities embedded in 1D or 2D background structures shows how these magnetic distortion effects may be recognized in GDS data.

MECHANICAL ENERGY FLUX TO THE SURFACE GEOSTROPHIC FLOW USING TOPEX/POSEIDON DATA

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The rate of mechanical energy transfer from the atmospheric winds to the surface geostrophic velocity is estimated for the world ocean. The surface geostrophic velocity is calculated from the 4 year mean dynamic topography and the 10 day anomaly fields obtained from the TOPEX/POSEIDON altimetry measurements. The wind stress is obtained from the NCAR/NCEP Reanalysis. An uncertainty estimate of the integrated energy transfer rate is more computationally demanding and therefore focused on just the North Pacific basin. The uncertainty is based on the geoid slope error estimates obtained from the JGM-3 geoid model coefficient covariance matrix. Despite the low signal to noise ratio, a meaningful signal can be extracted since the energy transfer calculation involves a projection of the estimated geostrophic current onto the wind stress field. The latter is more strongly correlated with the surface current than the geoid slope error.

BROADBAND MAGNETOTELLURIC DATA FROM CENTRAL JAVA, INDONESIA.

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Within the framework of the *MERAPI* (Mechanism Evaluation, Risk Assessment, Prediction Improvement) project, the electromagnetic group of GFZ Potsdam recorded broadband ($1000\,Hz - 0.0001\,Hz$) magnetotelluric data in central Java, Indonesia. The dat a were collected at 10 sites along a profile of about 150km in length in 1997. At least two regional conductivity anomalies can be identified in a generally very resistive crust: Induction arrows between $100\,s$ and $1000\,s$ indicate an extended area o f upper crustal high conductivity in the vicinity of the Merapi volcano, which is most certainly caused by volcanic and geothermal activity in a weakened crust. A second conductive feature in the nothern part of the island is probably connected with an a ctive fault system. Tensorial analysis of the data shows that the results at most sites can be explained by two-dimensional conductivity structures. Only the sites near the Merapi volcano show some three-dimensionality. The effects of the coast on the da ta are negligible.

RESOLUTION OF MANTLE HETEROGENEITIES FROM SIMULTANEOUS CONTINENTAL AND ISLAND ELECTROMAGNETIC MEASUREMENTS

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Many active tectonic environments are screened by deep, highly conductive oceans. Taking long period magnetotelluric (MT) data recorded simultaneously and continuously over a three month period on two Mediterranenan islands (Montecristo and Mallorca) we investigate the potential of electromagnetic induction data to resolve oceanic mantle conductivities despite the shielding and distortion effects of surrounding sea-water layers. It has been suggested that oceanic mantle is more conductive than continental, either due to its different chemical composition or because of its genesis in more recent tectonic activity. Hypotheses relating to mantle heterogeneity are examined in conjunction with MT data recorded simultaneously at additional sites (nominally 600 km apart). located around Heidenheim (Konstanz) and Clamecy (Orleans). and (in contrast) representative of tectonically stable, continental regions.

ELECTROMAGNETIC PROPERTIES OF THE SOUTHERN KENYA RIFT

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Magnetovariational (MV) and magnetotelluric (MT) data from 20 sites in S.Kenya reveal a complex structure. The dominant long period strike is not necessarily that of the north-south trending rift in this region, but rather trends oblique to it. The longer period induction arrows detect a significant NW-SE trending conductivity contrast, growing increasingly anomalous to the east of the rift. Variations in tipper magnitude along two profiles imply the presence of a number of geoelectric boundaries with varying strikes. The western margin of the rift appears as a strong discontinuity in both MV and MT data, whereas the transition from rift to eastern flank is apparently smoother. Skew values at many sites are large. Application of the Groom-Bailey decomposition to the impedance tensor fails to retrieve a stable, frequency independent strike and three-dimensionalities are implied. Certain features revealed by the data may relate to Protorozoic collision of the Archaen Nyanza Craton and Mozambique Belt and subsequent rift evolution in a region where the stress field has rotated remarkably quickly.

MT- AND DC-STUDIES CLOSE TO THE SAXOTHURINGIAN-RHENOHERCYNIAN SUTURE ZONE

Stoll, J.B., K. Bahr and A. Gatzemeier

The depth of investigation of DC-sounding methods is usually resctricted by the power of the current transmitter dipole and the noise and EM induction process observed at the receiver dipole. Especially in the case of long offset DC-measurements the DC signals range within the same order of magnitude as the noise and the inductive field. This prevents a proper estimation of the DC amplitude. However, if the EM impedance at the DC sounding site is known, the alternating electrical field can be predicted. This allows to remove the inductive field from the DC time series. Such combination of DC and MT-measurements was applied along two profiles close to the Saxothuringian-Rhenohercynian suture zone. The distance between the transmitter and the receiver dipoles of the DC-measurements was extended to 30 km at least. The DC-results are compared with the MT-studies, which clearly show anisotropic features within the middle crust.

APPROACH OF THE TECTONICAL ACTIVE ZONES (VRANCEA AREA) BY MT SOUNDINGS

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By correlating rigorously the magnetotelluric (MT) deep pseudosections, carried out for six MT profiles crossing the Eastern Carpathians and the surrounding areas, a few important data concerning the lithospheric dynamics, derived from the structure and the thermo-mechanical behaviour - so as it is revealed by the electrical properties, can appear. The main features of the crust and upper mantle are emphasized in order to outline especially the deep transition structure as well as the appearance of the sedimentary formations that mask it, by means of the structural elements. A discussion regarding some particularities at the transition zone (crust-upper mantle) level, reflected on electrical properties, is approached. The variation of the thickness of the crust (it ranges between 30-40 km beneath the Phanerozoic terranes , and 40-56 km beneath the East Proterozoic Plate, from North up to the Vrancea zone) denotes not only to what extent it was deformated during its evolution but can define a crack damage factor useful in predicting the stress-strain characteristics of the rocks for a certain microstructure. As concerning the depth of the lithosphere, it ranges between 150 km beneath the Eastern Carpathians (northern part) , exceeding 200 km in Vrancea region and amounting about 250 km in Tulnici zone. A cross pseudosection and a structural block-diagrama also reveal, for this zone, the maximum of thickening of the sedimentary formations, evaluated at 18 km.

MAGNETOTELLURICS AND SEISMOTECTONICS IN THE ALALYSIS OF ACTIVE DOMAINS : AN ESSENTIAL COMBINATION

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The geoelectric structural trends *(GST)* derived from the spatial analysis (rotation/decomposition) of MT and GDS data collected in active deformation zones, exhibit remarkable correlation with seismotectonic trends and nodal planes of earthquake mechanism solutions, in practically all cases we have examined in Greece and abroad. In several cases, the *GST* is consistent with apparent morphotectonic features and surface geology. In some, more interesting cases, the *GST* correlate with nodal planes which do not conform with existing views of the active tectonic modes of an area. In the upper crust of a tectonically active domain, the *GST* may be explained in terms of conductors formed by water infiltrating through fault planes and related discontinuities, aligned microcracks and anastomosing shear zones. Accordingly, the *GST* should be good indicators of the corresponding trends and the location of active faulting. In this context, the spatial information conveyed by the geoelectromagnetic data is as valuable in constraining the geometry of active faulting and modes of deformation. Characteristic examples from areas deformed by normal and strike-slip faulting are presented and discussed.

SE45 Observations of the electromagnetic field of the Earth in the Alpine-Mediterranean region

Convener: Smiljanic, N.
Co-Convener: Schnegg, P.-A.

Sponsorship: Geomagnetic Institute Grocka, Geomagnetism Group of the University Neuchatel

AN ARRAY STUDY OF DAILY MAGNETIC VARIATIONS IN YUGOSLAVIA

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The analisys of naturally occurring variations of the Earth's magnetic field is a well established technique for examining the electrical conductivity structure of the Earth. To obtain models of radial condactivity structure in a small limited part of the Earth, the three days of the diurnal magnetic variation have been analised as recorded by an array of three-component variometers sited on territory of Yugoslavia. The derived conductivity models are based on the magnetic field variation data having a characteristic time periodes ranging from 10 minutes to 24 hours, using different technique in dividing field components of the external and internal origine.

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4. Overhed and slide projector
5. Oral or poster

ELECTRICAL CONDUCTIVITY OF EARTH'S CRUST AND UPPER MANTLE IN CRIMEA

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More than 2000 magnetotelluric soundings (MTS) were made in Crimea. Cross section of sedimentary basins was studied in detail: total longitudinal conductivity make up 1000-1500 Sm in northern and 3000-5000 Sm in the eastern Crimea. Crustal conductors are observable on Tarhankut peninsula and in Crimean mountains but the latter conductors do not give rise to geomagnetic variations anomaly. Strong coastal effect from deep sea is characteristic of the southern part of Crimea. The complicated near-surface and crustal geoelectric conditions leave poor chances to investigate the astenosphere. The regional divergence of ρ_{NS} and ρ_{EW} in the northern part of Crimea suggests the existence of a meridional 100-200 km deep conducting strip but this version needs further confirmation. Detailed interpretation of several profiles is discussed. Large scale crustal conductor like Carpatian electrical conductivity anomaly have not been found in Crimean Alpine region.

MATHEMATICAL MODELLING OF SOME GEOELECTRICAL FIELDS IN 3D GRADIENT MEDIA

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This paper offers new, modem classes of mathematical models of geoelectrical fields in complex- structured 3D gradient media, i.e. in media with arbitrary 3D distribution of geoelectrical conductivity. The corresponding boundary value problems for the partial differential equations are reduced to systems of integral equations, whose approximate solution is obtained with numerical methods. The kernels of these systems are constructed by the Green's functions, which in a way take into consideration the specificity of the problem to a maximum extent. Integral equations are usually composed for all boundaries, where continuity of conductivity is disturbed. The heretreated method allows for reading to a maximum extent the complex structure of the medium by introducing Green's functions, taking at that a minimum number of surfaces, for which the integral equations are written. The models suggested here allow a maximum appreciation of complex-built structure of the geological medium by introducing Green's function for gradient semispace. Several various particular problems, to which the described method suggests an effective solution, are considered. Choise of the problems here was determined by the requirements of the theory of direct-current electrical methods.

CORRELATION BETWEEN GEOTHERMAL MODEL OF MACVA AND ELECTRICAL CONDUCTIVITY OF THE CRUST

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Mačva is a large alluvial plain in Serbia, Between the Drina and the Sava Rivers, some eighty kilometers west of Belgrade. Geotectonically, it lies on southern margin of the Pannonian Basin where it joins the Dinarides. The hydrothermal system of Mačva was discovered in 1982, when a high conductive geothermal anomaly was detected in deposits at Dublje, central Mačva. The acquired data indicate that the low-temperature convective hydrogeothermal system of Mačva is a part of a large regional system, extending under Mačva Semberija and Srem - a surface area of about two thousand square kilometers. A conductive geothermal anomaly, the highest in the Pannonian Basin was detected above the reservoir in central Mačva. This makes Mačva the Yugoslavian, and Serbian, "Red Spot", as the Pannonian Basin as for Europe (Horvath et al., 1979). Preliminary geothermal model of the Macva geothermal system indicate a feasible extraction of geothermal energy near Bogatić of thermal power no less then 150 MW. This paper presents the comperison between results obtained by geothermal model and magnetotellurics investigations

CONDUCTIVE STRUCTURE OF UKRAINIAN CARPATIANS FROM EM OBSERVATIONS.

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Geomagnetic variation observations in Carpathian region gave the data for tracing the axis of 1200 km long Carpatian electrical conductivity anomaly (CA) and estimation of its integral longitudinal conductivity (~3 $\cdot 10^8$ Sm$\cdot$m). We made also 35 MTS in the south-east part of the Ukrainian Carpathians. The shape of magnetotelluric curves regularly changes from north-east to south-west forming 6 zones of identical behaviour. Most interesting MTS curves are above the CA. The longitudinal curves define CA on the 10 km depth; the transverse ones are not sensitive to crustal CA but they define a mantle conductor on the 100-200 km depth with conductivity >5000 Sm which is probably the asthenosphere. CA transparency for transverse polarisation yields estimation of the anomaly width. Thus, the principal crustal conductors manifested by MTS data in Carpatians are CA subducting in south-west direction from moderately conductive sediments and a conductive zone of Transcarpathian deep fault. Correlation of electrical conductivity structure with seismisity and thunderstorm activity is discussed. Geothermal data and geodynamic history are used for explanation of CA formation and nature.

THE ELECTRICAL CONDUCTIVITY OF THE CRUST AND UPPER MANTLE IN THE SOUTH EAST EUROPE AND THEIR TECTONIC SIGNIFICANCE

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The sounding of the crust and upper mantle have been carried out in the South-East Europe (former Yugoslavia and surroundings) during last 30 years in field campaigns of deep magnetotelluric and magnetic soundings as well as during magnetic measurements on the repeat stations. This results have been used to study distribution of the electrical conductivity in different tectonic units such as the Alps, the Dinarides, the Vardar zone and the Pannonian basin. Results show close connection between geological structures and induction arrows especially in the Dinarides and the Vardar zone. The conductivity of the crust is enhanced in some mobile belts inside the Dinarides and in the Vardar zone and along Sava and Danube. I construct 2-D model for two regional profiles from the Adriatic see to the Pannonian basin. They show that the conductivity layer in the upper mantle is about 200 km in the area of the Adriatic coast and below 100 km in the inner Dinarides, the Vardar zone and the South Pannonian basin. Comparison with DSS and the heat flow map show good correlation with regional geoelectrical structures. Along ophiolitic belts we have high conductivity within lower crust which need more detailed soundings for resolving their connection with tectonic, which is the main goal of the runing project.

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LITHOSPHERIC THICKNESS IN THE REGION OF THE ST. HELENA HOT SPOT FROM SATELLITE DATA

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The St. Helena Hot Spot is located at the western end of the 2000 km long Cameroon line, 500 km east of the Mid Atlantic Ridge (MAR). Model calculations have been executed at the hand of the relative young seamounts Kotusov and Josephine (7–9 million years old). The data base consists of the bathymetric data set GEODAS from NOAA with complementary measurements during the marine campaign SO94 of the German research vessel SONNE and satellite gravity respectively geoid data from the ESA-ERS 1 mission. 3D elastic lithospheric flexure and gravity models have been calculated with the programme code of Weddeling (1996). It can be demonstrated that the global gravity data set with a grid width of 5 min. provides an unsufficient resolution for modelling of the structures. But the inclusion of geoid data of single track profiles allowed reasonable results. The resulting effective lithospheric thicknesses range from 7 to 10 km. This is less than the expected value of 20 km for a 36 million years old lithospheric plate but larger than for comparable Polynesian hot spots. This is indicative either for a "weak" mantle plume or for a connection of the magma transport system with MAR.

Weddeling, P. (1996): Flexure of the lithosphere due to the Canary Islands and its influence on the sediment stratigraphy of the adjacent west Saharan margin. Diss., Kiel.

ARCHITECTURE AND CRUSTAL EVOLUTION ACROSS THE EPR AT 22 N FROM THE SOUTHERN TIP OF BAJA CALIFORNIA TO PUERTO VALLARTA

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The achievement of a geophysical transect, during the CORTES-96 project, along more than 300 km from Puerto Vallarta to Los Cabos (southern tip of Baja California) yield new views of the lateral crustal variation from accretion at the East Pacific Rise (22N) till the contact with the continental basement of the Rivera Plate. Multichannel seismic profiles, swath bathymetry, gravity and magnetics data were acquired along this transect. Moreover, wide-angle and refraction seismic profiles recorded in 6 OBS, located at both sides of the EPR, constraint the contact between the oceanic and continental crust. The eastern most magnetic anomaly identified in the area is the anomaly 2A (3.5 Ma), placed near the Maria Magdalena Rise (MMR). The MCS profile close to the MMR shows scarce sedimentation and high reflectivity suggesting an oceanic basement outcrop or a volcanic structure. The integration of the different data along the transect define the crustal architecture at the contact between the crust generated at the East Pacific Rise and the crust at the Rivera-North America plate.

GEOPHYSICAL STUDIES IN THE MEDITERRANEAN SEA DURING METEOR CRIUSE NO. 40/1

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The Mediterranean Sea has a very complex structure. Therefore, its investigation needs a complex strategy of methods to be applied. Since none of the parts of the Mediterranean Sea is representative for the whole area, several sections have to be studied. The problem of seismic penetration requires sometimes the acquisition of other information such as gravity, magnetics, sediment cores etc. During the Meteor 40/1 cruise (November 1997) a combination of above mentioned methods were deployed in order to study relief types and subbottom structures. Along several profiles in four different areas gravity, magnetics and bathymetric data were collected. The data acquired during this cruise are combined with the geophysical results of Valdiva 120, Meteor 25 cruise and other available data in the research area.

We present the gravity and magnetic anomaly maps of the area and will discuss some crustal models obtained from these data.

TRANSVERSE FAULTS IN THE TROPICAL ATLANTIC FROM KANE TO ROMANCHE: SIMILARITIES AND DISTINCTIONS

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Various segments of the ridge show many similarities, but they also exhibit a number of fundamental distinctions between their potential fields, geochemical characteristics and their deep structure. Novel and quite unexpected results were obtained using combined analysis of the gravity field and bottom relief thin structure and available seismic and geochemical data. It was found that fracture zones (FZ) similar in their bottom relief (for example, Kane and Verna/Vernadsky) exhibit clear distinctions in their deep structure and even more in the mineral composition and geochemistry of dredged samples. Not all of the surveyed FZ can be classified as transfom faults. Kane, Verna and Chain with their thin crusts, specific seismicity, etc., are likely to be transform faults. But the area south of 10°N (which includes the Doldrams and Vernadsky) and, probably, the Romanche fault exhibit distinct ancient geological features such as thick, mostly low density crust, density inversions, numerous dredged samples of serpentinites and limestones. Therefore, the above-mentioned FZ, particularly Vernadsky fault, close resemble typical rift zones, which proves that the transform mechanism cannot adequately explain the processes assosiated with these FZ. Moreover, it was shown that in Romanche, Vernadsky and 15°20' FZ tectonic processes prevail [Kogan et al., 1985, Pussharovskii et al., 1988]. Spreading with fresh basalt effusion has been proved for Vernadsky fault.

SEDIMENT SUBDUCTION/ACCRETION AT THE CHILEAN CONVERGENT MARGIN BETWEEN 35° AND 40° S

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Four multichannel seismic reflection lines (called from N to S ENAP-1, 2, 4 and 6) collected off south-central Chile were processed using conventional methods and partly using pre-stack depth migration. The seismic images reveal a tectonic pattern consisting of mainly four zones from W to E. **The zone of compression** displays a trench axis almost completely filled with turbidites. Trench fill thickness remains constant along margin, with the exception of line ENAP-6. Its sea floor plunge downward to the north. Below, the oceanic plate is cut by large normal faults, causing at line ENAP-2 horst-graben structures. The zone of compression is best recognized at line ENAP-4, because of a series of high-angle (conjugate) reverse faults. Beneath **the lower continental slope** a moderately sized accretionary prism overlays a channel of subducted sediments; a big amount of them being later underplated. To the east, the backstop seems to be part of old accreted sediments. **The upper continental slope** contains a BSR, which is however almost upsent in line ENAP-4. Along ENAP-6 the continental slope is much wider, and therefore gentler, than to the north. Slope cover sediments are moderately thick and partly deformed and thrusted. Finally, **the continental shelf** is underlain by a sedimentary basin, which varies greatly along margin in the degree of deformation.

QUANTIFYING ACCRETION IN THE CASCADIA SUBDUCTION ZONE OFF WASHINGTON

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Based on multichannel seismic reflection and coincident wide-angle data collected in April and May 1996 aboard the German research vessel SONNE, we investigate the style of sediment deformation in the Cascadia convergence zone. Cascadia is unusual in the sense that frontal accretion occurs along landward verging faults. We used combined iterative prestack-depth migration techniques together with velocity analysis from wide-angle recordings to construct an optimum depth section for detailed structural balancing. Seismic attributes were used to constrain physical properties within the sediment, and allow coupled hydrothermal model calculations. These indicate that elevated pore pressure, caused by tectonic dewatering at the first ridge, begins seaward away from the deformation front, where ridges start forming. Section restoration and depth to detachment analysis shows that 80% of the incoming sediment is accreted. Within the frontal accretionary wedge, consisting of three ridges, the amount of shortening is equivalent to the total plate convergence of only 200000 years. This 30 km wide part of the wedge accommodates 25% (8 km) shortening.

HIGH RESOLUTION SEISMIC INVESTIGATION OF THE CONTINENTAL MARGIN OFFSHORE VALPARAISO, CHILE

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In 1995, approximately 2000 line km of high resolution reflection seismic data were acquired along the continental margin offshore Valparaiso, Chile, as part of the multidisciplinary CONDOR program, conducted by GEOMAR. The survey area covers a two degree segment extending from the shelf edge, crossing the Chile Trench to the eastern limit of the Juan Fernández Ridge. The seismic aquisition equipment consists of a 24-channel, 150 m long active streamer and a cluster of 4 sleeve guns with a total volume of 160 cu. inch. Data were processed using the software packages of GEOSYS and ProMAX (6.0). Poststack bandwidth of the data is 40-180 Hz. On most profiles, seismic penetration reaches 1-3 s TWT, depending on sediment and rock types. Between 32_30' and 33_00'S, the seismic data reveal a large fore-arc basin in a mid-slope position, - named the Valparaiso Basin. The basin is bounded to the north by a NE-SW striking topographic ridge, which is the surface trace of the eastward subducting Juan Fernández Ridge. As the subducting ridge strikes obliquely to the direction of underthrusting, the locus of the point of descent progressively moves southward along the trench through time causing a progressive uplifting and narrowing of the middle-slope Valparaiso Basin. Erosion and gravitational collapse of the uplifted slope and hence destruction of the fore-arc basin accompany subduction of the ridge.

ISOCHRONOUS CHANGES IN THE IMAGES OF THE CRETACEOUS OCEANIC CRUST OF THE ANGOLA BASIN/SOUTH ATLANTIC

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Along our MCS flow-line transects (> 40000km), located north and south of the Rio-Grande-Rise/Walvis-Ridge, we observe systematic and isochronous structural changes in the seismic images of the oceanic crust of the South Atlantic basins. We can demonstrate the presence of four major crustal categories within the Cretaceous oceanic crust of the South Atlantic. Two of these categories are characterized by strong lower-crustal reflectivity and very thick igneous crustal units (determined from seismic refraction results). One of these categories shows a flat basaltic basement and a sequence of seaward-dipping reflectors beneath. Our preferred explanation of the isochronous changes in the seismic images is, that there was some form of episodicity between rich magma (heat) supply (Hot Period) and poor magma (heat) supply (Cold Period) in the accretionary processes at the former mid-ocean ridge leading to a cyclic generation of lherzolite-type and harzburgite-type ocean crust. In order to test our theory on cyclic crustal accretion and variations in mantle temperature we propose to drill six holes in the Angola Basin by the ODP-program.

POSSIBILITIES OF HIGH-PRECISION MARINE GRAVITY FOR THE STUDIES OF THE MAJOR STRUCTURES OF THE OCEAN BOTTOM

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As gravity was measured on board a moving vessel, significant dynamic errors (about 20-30%) in observed local gravity occurred, causing similar errors in the density for the blocks 20-30 kms long. The algorithms of signal restoration were applied to compensate for distortions of useful signal due to the filtration characteristics of the gravity meters [Panteleyev, 1983]. Cross-correlation analysis of the measured and modeled gravity fields using known gravimeter characteristics was employed for the signal restoration. Local anomaly values corresponding to the maximum of coherence function and the minimal phase angle were regarded as correct. Only after the signal restoration using a σ-block program [Berezhnaya and Telepin, 1982], the density of the crust was calculated for a number of rift zones, rifted margins, transform faults, etc. The surveyes performed in a number of test areas (Kuril-Kamchatka trench, Kane fracture zone, Philippine Sea, etc.) yielded the results of the much higher accuracy (about 0.5 mgal) and in more detail. Thus, the greatest transformation (up to 50 mgals) occurred in the local anomalies measured over the arch-trench systems which caused a considerable density changes in a subduction slab model and margin sea crust. Basing on these results the new ideas concerning the crust and upper mantle density occurred which are discussed in the report.

COLLOCATED IMAGERY AND BATHYMETRY MAKES THE SUPER FAST EAST PACIFIC RISE INTO STEREO VIEW

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The crest of the 13 deg S-19 deg S super-fast spreading segment of the East Pacific Rise is incised throughout its length with a narrow, steep-sided axial trough, previously recognized only at isolated locations. Its origin has been vigorously debated as either an axial caldera or as an axial rift graben. New long-range, high resolution collocated swath imagery and bathymetry, processed into stereo pairs, shows that the trough exists all along the ridge crest, and also reveals new details of fault and volcanic relationships along the ridge crest and flanks. The axial trough is an extensional rift graben along which volcanic flows alternately fill, cool and drain leaving caldera-like collapse structures, bury and overflow the rift onto the ridge flanks and adjacent seafloor. Rift faults are completely covered by flows as spreading proceed. Faulting on the ridge flanks is in response to vertical stresses between the axial crust, buoyed up by shallow magma, and the adjacent cooler and much thicker crust at the base of the ridge flanks. These faults generally face seaward and are commonly draped with lava flows. Faults formed at the base of the ridge flanks generally face toward the ridge, are not commonly draped with lava flows, and are formed in response to horizontal stresses related to plate motion.

GRAVITY AND SIDE-SCAN SONAR STUDIES IN THE ROCKALL AND PORCUPINE TROUGHS, OFFSHORE IRELAND

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The marine free air gravity and derivative maps for offshore Ireland reveal a series of gravity features related to the structural and crustal make-up of the region. Dominant NE-SW trending fabrics are interpreted as Caledonian in origin and played a major role in the development of the Irish Offshore Basins. Transverse NW-SE lineaments are also identified. They coincide with major offsets and changes in basin margin geometries in the Rockall Trough, Porcupine and Celtic Sea Basins. The Charlie Gibbs Fracture Zone and the ESE-WNW trending Clare 'Lineament' appear as distinct gravity features and the Clare Lineament continues across the Porcupine Bank. Cretaceous and Tertiary igneous provinces, such as the Porcupine Median Volcanic Ridge, Barra Volcanic Complex and the Brendan Centre show as major gravity highs. Distinct gravity anomaly minima in the Rockall Trough are caused by lower-crustal thickening and gravity edge effects. Gravity lows in the Porcupine may represent the presence of low-density igneous bodies. Canyon systems mapped with long-range side-scan (GLORIA) data on the Porcupine Bank correlate with bathymetric incisions into the bank defined by gravity. These canyons trend oblique to the basin margins and appear to be related to regional gravity fabrics.

SEISCAN – EUROPEAN MARINE SEISMIC ARCHAEOLOGY

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SEISCAN is a seismic archaeology project in the MAST-III Supporting Initiative programme. The objective is to rescue the academic seismic reflection profiles, collected since the 1960s, that remain only as paper records. The project will compile metadata on records acquired in European waters and organise digital scanning throughout the EU at no cost to the contributing organisations. The electro-sensitive EPC linescan records in question are readily handled by modern scanners. SEISCAN is being co-ordinated from Southampton with the four other research centres. The partners will be responsible for liaison with other centres throughout Europe in co-ordinating information to the scanning operations in Barcelona and Strasbourg. Processing will be carried out to specific quality control criteria. This will include enhancement to the scanned images to compensate for background variations from fading and the application of electronic deskew and despeckle using commercial imaging software. Images created by the project will be copied to CD-ROM with associated navigation files. This will provide access to the legacy of 30 years' research funding.

TECTONIC SETTING OF THE LOGACHEV HYDROTHERMAL FIELD (MAR, 14°45' N).

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The *Logachev* hydrothermal field is situated on the middle part of the eastern rift valley wall, 1000 m above the inner floor. Different from other hydrothermal areas, *Logachev* sulfide deposits lie directly on ultramafic rocks. The eastern valley wall is anomalously high and wide. It is mainly composed of serpentinized peridotites with local gabbroic intrusions. Basalts were detected only at the base of the wall (4 km away from the hydrothermal site) during the Nautile dive (MICROSMOKE cruise, 1995) and also were dredged immediately on the summit. Thus, the most part of the valley wall was formed in the process of the tectonic extension during the amagmatic spreading phase. The very complicated morphology of the wall is determined by combination of linear (along-axis and transverse) and hook-like highs and deeps. This structure might have been formed in this area due to combined effect of prolonged mainly amagmatic crustal extension along a low-angle detachment fault and protrusions of buoyant serpentinite diapires in zones of steep along-axis and transverse faults. High-permeability zones created in time of the tectonic extension phase became the pathways for lateral magma and/or hydrothermal fluid migration during the following episodes of volcanic activity on the axis. Three periods of sulfide formation (66-50, 33-20 th. yrs. ago and modern) can be related to three volcanic events inferred from the sediment thickness data obtained by submersible observation.

SEDIMENT VELOCITY ESTIMATION IN SHALLOW WATER CONFIGURATION

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Usually, the estimation of velocity in sediments is straight correlated to the refracted waves. However, in shallow water (less than 200 m) and for a 2-50 Hz bandwidth, the frequency dispersion affects strongly the acoustic and seismic wave propagation. In this case, two important physical parameters must be considered : the water depth and the velocity discontinuity between the water layer and the first sedimentary layer. This paper deals with an example of a weak step of velocity and a 70 meters water depth. The receiver is laid on the sea-floor, recording a signal issued from an airgun located near the sea-surface (10 m). Shots are regularly emitted over a distance of 14 km. In this context, a complete velocity analysis and a modelling with the normal mode theory allow to understand all the wave propagation. The various wave guides including water show some frequency dispersion effects. The fast refracted wave is not affected because it propagates mainly in sediments. The refracted and reflected waves arriving later are more concerned with these dispersion effects. Signals that propagate mainly in the water allow to estimate the two physical parameters. With these estimations, all the effects of various wave guides on refracted and reflected waves can be corrected. The normal mode theory confirms all these results on field data. Based on field data and modelling, our method allows to measure the wave propagation velocities in underwater sediments, despite the dispersion effects of the various wave guides.

MODELING OF THE AZIMUTHAL ANISOTROPY HEAT CONDUCTIVITY OF THE OCEAN UPPER MANTLE

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By method of conditional moments for lherzolite model of ocean upper mantle with with space orientation of the spheric olivine and pyroxene grains are calculated heat conductivity tensor components for depthes. The heat conductivity anisotropy coefficient is decreases from 16 % to 14 % on depthes 10-15 km, and then increases to value 17 % with depth. The presence of the horizontal component of the conductive thermal stream in plastic current orientation, together with mass advection causes latheral temperature gradient, partial fusibility of asthenosphere and its reologic stratification. It can enlarge thermal losses upper mantle at transformation of the thermal energy in mechanical. The obtained results corresponds to seismic anisotropy of the ocean upper mantle.

MECHANISMS OF SUBDUCTION ACCRETION ALONG THE OBLIQUE CONVERGENT MARGIN OFF SOUTHERNMOST CHILE

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The Southernmost chilean margin was investigated during 1995 and 1997 in the frame of the Italian Antarctic Program (PNRA) by the R/V OGS-EXPLORA. Seismic, gravity and magnetic data were collected between the Strait of Magellan (51 S) and Cape Horn (57 S). The subduction complex records the complex tectonic history of the area from Paleozoic to recent times, which is characterised by different phases of accretion, non-accretion and tectonic erosion. The present day accretionary wedge and forearc basin are related to the recentmost Cenozoic convergence between the Antarctic and Scotia plates, which resumed after the consumption of the Chile mid oceanic ridge below the Chile trench (14 Ma). Structural style and geometry of the accretionary complex vary along the margin. Variations in the depth of the dÜcollement level, obliquity of convergence and width of the terraced continental slope are the parameters which seem to control structural variability. Low taper angles, lower strain rates and mixed structural vergence are related to a deeper dÜcollement level and a wider continental slope. On the contrary, large tapers, seaward vergent structures and the lack of a proto-thrust domain at the toe of the accretionary wedge are related to a shallower dÜcollement and a narrower continental slope. One profile has been processed at the Geomar processing center applying pre-stack depth migration. The new migrated profile improves the seismic image of the accretionary wedge, allows the recognition of the true geoemtries in depth and shows that the landward vergent strucutres are not peculiar of the proto-thrust area but are present also inside the accretionary wedge.

STRUCTURE OF THE SANDINO FOREARC BASIN, PACIFIC MARGIN ON NICARAGUA

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Three reprocessed multichannel seismic reflection sections across the offshore part of the Sandino Basin comprise a cross section about 100 km long. The cross section traverses from near the shoreline to the upper continental slope, near the Middle America Trench. In addition to standard processing, we obtained depth sections through iterative pre-stack depth migration. The result is an accurate depth section to about 8 km depth. We have mapped the seismic basement and define 6 seismic stratigraphy units based on structure of the strata, their seismic character and velocity information. Two wells provide ages of the main seismically defined units. Detail velocity information obtained from focusing analyses has been used as an indicator of possible lithology. A major event in the tectonic history of the basin was uplift of the 30 km wide tract that currently forms the edge of the continental platform. Major uplift was between early Eocene and Oligocene time. In the center of Sandino Basin two folds display a growth history since pre-Eocene time as well. The most important tectonic episodes are clearly correlated to the global kinematics of the major lithospheric plates in the area.

SEDIMENT THICKNESS IN THE WESTERN WEDDELL SEA (ANTARCTICA)

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The Weddell Sea is one of the key regions for a better understanding of the geodynamics of the Gondwana breakup which started 180 million years ago. Important informations about the tectonic processes that are involved in the continental breakup can be derived from the distribution of sediments and their structure. Due to the ice conditions in the Weddell Sea region there are mainly potential field data available.
For a better interpretation and calibration of these data there is a need for reflection and refraction seismic measurements that yield direct information on sediment and crustal thicknesses. During the austral summer season 96/97 seismic reflection data were collected in the non-ice covered area of the western Weddell Sea. In addition, we acquired wide-angle data from drifting ice floes for accurate velocity determination of the sediments. Seismic reflection data in the south western part of the Weddell Sea show sediment thicknesses up to 3 s TWT. With P-wave velocities derived from the wide-angle measurements this corresponds to a total thickness of 4-5 km. Furthermore a prominent gravity anomaly at 68° S was investigated by the seismic network. The data reveal that the gravity anomaly is caused by basement highs fully covered by sediments.While in the eastern part the basement ridges have a width of 15 km, the structures broaden to 25-30 km towards the west.

BACK-ARC OPENING AT THE TRANSITION FROM THE LAU BASIN TO THE HAVRE TROUGH (SW PACIFIC).

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The Lau Basin and the Havre Trough are two continuous active backarc basins extending over a length of 2700 km at the Pacific-Australian convergent plate boundary, in the SW Pacific. The Lau-Havre system opens since 5.5 Ma, between the Tonga-Kermadec arc-trench subduction system and the Lau-Colville remnant arc ridge, with a rate increasing from south to north, from 1.5 cm/y to 11 cm/y. The main focusses of the Lauhavre 97 cruise (Japan-France New-Starmer programme) were the mecanism and the evolution of back-arc opening from initial rifting to full oceanic spreading, from the Havre Trough to the Valu Fa spreading center in the southern Lau Basin, the influence of the Louisville Ridge and Pacific slab subduction on the back-arc basin tectonics, volcanism and hydrothermalism.
The bathymetric, seismic reflection, magnetic and rock sampling data collected allow to built a new structural frame and to propose a new tectonic and kinematic evolution model of the spreading opening for the Lau-Havre transition zone. The Valu Fa spreading presently propagates southward up to 23°40'S, inside an older back-arc aera, whereas the rifting seems stopped in the northern part of the Havre Trough, in response to the subduction of the Louisville Ridge at 26°S.

MORPHOLOGIC ANALYSES OF SPREADING CENTERS BY IMAGE PROCESSING

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High resolution of recent multi-beam echo sounders collected on wide area along spreading centers reveal a detailed relief characteristic of the crustal bending. The main submarine geological structures can be directly extracted from the numeric bathymetry by pattern recognition. The principal advantage of this method is to automate the detection of structures in order to obtain unbiased results from well-defined criterions and to realize quantitative studies on the geological structures. We present two methods of pattern recognition based on the derivatives of the bathymetry. The first one is the detection of seamounts. These general shapes of domes are defined by positive maximal and minimal curvatures and are labelled on the image. The second one is the detection of faults which is performed with tools of edge detection particularly used in artificial vision. The relatively fast variation of the relief is detected by maxima of gradient. This quantitative study applied to the bathymetry of a marginal basin (the North Fiji Basin) constrain the distribution and the evolution of tectonic and magmatic processes along the ridge.

MORPHOTECTONICS OF THE MAKRAN ACCRETIONARY WEDGE

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During RV Sonne cruise SO 123, an area of about 10000km^2 of the Makran accretionary wedge off Pakistan was surveyed with swathmapping and Parasound echo sounding.

The morphology of the wedge is characterized by several steep accretionary ridges separated by remarkably flat areas with undisturbed sedimentation. While the protothrust is at different stages of development along the margin, and the older accretionary ridges are of limited length, the first ridge is surprisingly homogeneous and steep with an elevation of up to 1200m above the abyssal plane.

East of 62° 50', several zigzag shaped eroding canyons cut the whole wedge. Some of these canyons appear to be active flow conduits.

Shortening is accomplished completely by the formation of the accretionary ridges with even the most landward ridge showing active thrusts.

SEISMIC FACIES AND GLACIOMARINE SEDIMENTATION IN THE SOUTHERN WEDDELL SEA

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About 14.5 Ma ago the final steps of the Gondwana breakup allowed the seaways around Antarctica to open. Consequently, the continent was isolated from the warmer climate of lower latitudes. This gave rise to the development of the Antarctic ice sheet in its present shape. Anyhow, several advances and retreats of the ice masses occured since the Eocene, eroding vast areas of the continental shelf and leaving characteristic seismic sequences, e.g. prograding reflectors, at the shelf edge.
Changes in discharge of grounded ice sheets and thus variations in extension of the large Antarctic ice shelves are closely associated with global sea level changes. The Filchner-Ronne Ice Shelf (FRIS) is the most extensive body of floating ice in the world and hence, its global significance is evident.
Remnants of former expansions of the FRIS are found mainly in the eastern parts of the shelf edge off the FRIS. Because of the glacial overcompaction, MCS data in this area suffer from severe multiple contamination. Application of dip filter and inverse velocity stacking techniques on data collected by the AWI in 1995 unmasked glacial structures in the seismic sections east of 40°W. However, a significant westward reduction of glacial influence is being revealed. Seismic profiles located in front of central FRIS at 40°W show little evidence of glacial advances to the shelf edge.

TICOSECT/ COTCOR: RESULTS OF WIDE-ANGLE INVESTIGATIONS ON AND OFFSHORE COSTA RICA

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In 1995 and 1996 two experiments were carried out on- and offshore Costa Rica. During the 1995 TICOSECT project, both ocean bottom hydrophones/seismographs and landstations recorded several profiles of airgun shots fired aboard the R/V MAURICE EWING in three survey areas along the Pacific margin.
In 1996, during the COTCOR project, two continental transects were completed using land recordings of signals from explosive sources.
We present results of two areas: First, the South Costa Rica transect, from the Middle America Trench near Bahia de Coronado across the Talamanca Cordillera to the backarc basin near Limon. We discuss the image of the subduction of the aseismic Cocos Ridge and compare it with results of investigations further north in Costa Rica and Nicaragua. The subducting Cocos Plate has a thickness of app. 12 km, much thicker than the oceanic crust further north. It dips with an angle of only 12 degrees underneath the Talamanca Cordillera. Down to a depth of more than 20 km a zone of lower velocity could be detected. This layer marks the boundary between the subducting plate and the laterally homogenous high velocity block of the landbridge, which extends about 30 km seaward on the Pacific margin, forming the backstop there.
Wide-angle studies off- and onshore the southern edge of the Nicoya Peninsula and the adjacent Gulf of Nicoya are also shown. Here the 3d velocity structure was calculated by iterative raytracing and automated inversion algorithms of wide-angle data. A model of the shelf could be generated to a depth of 15 km showing the general seaward continuation of the ophiolithic complexes with their relatively high velocities. Locally, sedimentary basins overlay the ophiolithic basement, indicating tectonic movements of the margin.

THE SEISMIC EXPERIMENTS AT THE NORTHERN END OF THE HAVRE TROUGH

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The Lau Basin and the Havre Trough are active back-arc basin associated with the subduction of an oceanic crust under an oceanic arc. To clarify the seismological feature, we carried out the seismic experiment using Ocean Bottom Seismometers (OBSs) and a single channel hydrophone streamer. The result shows the major features of the velocity structure around the northern Havre trough: (1) An upper crust consists of the 4-5 km/s and 6 km/s layers. (2) The P-wave velocity of the lower crust is about 7 km/s. (3) The major feature is variation in the velocity structure between northern part from 26S and southern part. The differences appear in the crustal thickness and the P-wave velocity of the lower crust. The thickness of the crust of the northern part is about 9 km and that of the southern part is about 10 km. The P-wave velocity of the lower crust of the northern part is 7.0-7.1 km/s, and that of the southern part is 6.8-7.1 km/s. We also found that two seismically active regions are detected outside of the OBS array; one is bathymetric high area between the Lau Basin and Havre Trough; the other is beneath the landward slope of the Kermadec Trench.

FROM COCOS TO CARIBBEAN PLATE - GEOPHYSICAL INVESTIGATIONS AT THE PACIFIC COAST OF NICARAGUA

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In early 1996 bathymetric, magnetic, active and passive seismic measurements were carried out offshore Nicaragua. The major objective is to reveal the transitional structure between Cocos and Caribbean Plate. A 335 km long refraction profile extended from the Cocos Plate across the Middle American Trench to the continental margin of the Caribbean Plate in Nicaragua using airguns as source and ocean bottom hydrophones (OBH) as well as landstations for recording. Two 100 km long strike profiles were situated 40 and 70 km landward from the trench. OBH spacing was 10 - 25 km. In addition to the permanent seismological net on land, a 100 km^2 temporary array of 9 OBH monitored the local seismicity for ten days.

The results show a 5.5 km thick oceanic crust with a thin (<0.5 km) sedimentary cover. Near the trench it dips with 5°, 60 km landward the dip is 15° and 100 km from the trench it reaches 23°. Bathymetry displays only a small prism of accreted sediments. Under the thin sedimentary cover of the steeper continental slope and the well developed forearc sedimentary basin in the shelf area wide angle seismic velocities range from 4 to 5 km/s. Together with reflection profiles this acoustic basement is interpreted as ophiolitic crust, similar to the Nicoya-like lithology of Costa Rica. In the basin area these rocks are overlain by carbonate-rich paleocene-eocene sediments of similar velocity. The most striking feature is a shallow mantle slab between the continental and subducting oceanic crust in a depth of 15 to 40 km.

CRUSTAL STRUCTURE AND MAGMATIC UNDERPLATING BENEATH TAHITI, SOCIETY ISLANDS

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We analyze the crustal and upper mantle seismic structure beneath Tahiti, French Polynesia, using wide-angle seismic data. Eight refraction profiles from PASO-94 experiment (April 1994) were recorded in 11 portable land-stations and 9 ocean bottom seismographs. The experiment was designed to provide good ray-path coverage, in order to obtain the P-wave velocity structure by applying a three dimensional tomographic inversion of the observed arrival times. Theoretical travel times are calculated using a finite-difference algorithm, which is accurate for large velocity variations and regions of extreme topography. Two radial profiles north and south of Tahiti exhibit normal upper mantle velocities (>7.8 km/s), evidencing the lack of underplated material beneath the island. However, a thick (1.6-2.4 km) layer with velocities from 4.4-4.9 km/s is identified over the pre-existing oceanic crust, and is interpreted as volcanoclastic material derived from the island. A three dimensional analysis of the P-wave structure around and beneath Tahiti will better constraint the volume and extension of the underplated material, if any, and thus provide accurate estimates of the amount of volcanic material supplied by the Society hotspot.

SUBMARINE MORPHOLOGY IMAGED BY HIGH RESOLUTION BATHYMETRY

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In marine environments, the surface of the solid earth is covered by water and can only be mapped with bathymetric methods. As the seafloor is built up by internal and external forces, the submarine morphology preserves information on internal structures and tectonic history.

Multibeam echosounding systems continuously map a stripe of the ocean bottom with an acoustic swath. The echo data is processed to calculate a digital terrain model, which can be presented as a bathymetric map or a perspective view. Using calculated illumination details in the images are enhanced, thus revealing much more morphotectonic information than in custom bathymetric maps.

Seamounts and active continental margins are striking features of submarine morphology. The dynamic history of these areas is demonstrated in bathymetric images.

SE47 Structure and composition of oceanic lithosphere

Convener: Danobeitia, J.

01 Rifted margins

Convener: Reston, T.J.
Co-Convener: Sibuet, J.-C.

DEEP CRUSTAL STRUCTURE OF THE VøRING BASIN: A COMPARATIVE SENSITIVITY ANALYSIS OF OBS AND ESP DATA

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The Vøring Margin of mid-Norway is characterised by extensional tectonism and voluminous early Tertiary continental break-up volcanism. Knowledge of the deep crustal structure in this area is crucial for the understanding of rift-related processes (e.g. mode of rifting, magmatic underplating) and the quantification of extension and the thermal history. Here, we discuss the resolution and reliability of Ocean Bottom Seismograph (OBS) and Expanding Spread Profile (ESP) data. In the lower crust the resolution of the wide-angle data is mainly dependent on the ray coverage, which in turn is controlled by the geometry of the entire crustal structure. In the few cases where arrivals can be identified uniquely vertical resolution is about +/- 500 m and the velocity resolution +/- 0.3 km/s. However, at one crossing between OBS and ESP transects we determine a 1.5 km difference in depth to Moho. Only three arrivals, including the Moho wide-angle reflection, can be identified with high reliability. Numerous other events are interpreted to originate from smaller bodies. Modelling shows that bodies of a horizontal extent of less than 5 km will be ambiguously identified in the seismic data, yielding a wide range of possible geological interpretations.

STRUCTURE OF THE 120 KM-WIDE OCEAN-CONTINENT TRANSITION OF THE IBERIA ABYSSAL PLAIN MARGIN (PORTUGAL) : PRELIMINARY RESULTS OF THE ODP LEG 173.

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Seven basement highs were sampled by drilling in the ocean-continent transition (OCT) of the Iberia Abyssal Plain. Five new holes drilled during the ODP Leg 173 (april-may 1997) complete the transect through the OCT previously explored during leg 149. From east to west, the preliminary drilling results and the multichannel seismic data allow (1) to better constrain the location of the eastern limit of the OCT at the foot of Site 1065 high, which is most probably the deepest tilted continental block of the margin; (2) to sample a possibly syn-rift tectonic crust-mantle boundary between mantle melt products (intensely sheared gabbros, amphibolites with intrusive meta-anorthosite and tonalite, sites 900 and 1067) and mantle rocks (plagioclase and spinel-bearing peridotite, Site 1068), which is imaged as a strong intrabasement reflector; (3) to sample a continental fragment (Site 1069) isolated between mafic and/or ultramafic rocks, which is the southern end of the Galicia Bank; the strong intrabasement reflector which underlines this high is most probably a tectonic contact; (4) to sample a 3 m-thick body of pegmatitic gabbro intruded into spinel- (and rare plagioclase-) bearing peridotites (Site 1070), which could represent early formed oceanic seafloor.

A preliminary tectonic model of formation of the margin and the adjacent OCT is proposed.

CRUSTAL STRUCTURE FROM GALICIA INTERIOR BASIN TOWARD THE IBERIAN MASSIF

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A seismic experiment carried out in July-August 1997, examined the deep crustal structure of the Galicia Margin. The large airgun seismic source supplied by the R/V Maurice Ewing allowed to record excellent data up to 350 km inland. Two main E-W profiles perpendicular to the shore recorded these marine shooting in 10 OBS-OBHs and 25 portable landstations, providing good sampling of the ocean continent transition zone. The continental domain is characterized by extensive Hercynian outcrops (i.e. Iberian Massif) and the oceanic domain is formed by rotated fault blocks like structures features that furnish information on the initial rifted period. In this wide crustal domain we do have clear reflection and refraction phases (Pg, Pn, PmP) appropriate to analyse the crustal deformation style of the N-S trending Galicia Interior basin toward the stable Iberian Massif. A crustal model mainly based on the information recorded by 25 landstations deployed along two profiles perpendicular to the shore will provide significant constraints on the geometry of the rifting sequence, along the Northwest Iberian Margin, prior to the oceanic spreading during Jurassic-Early Cretaceous time.

ONSHORE-OFFSHORE CORRELATION OF BASALTIC FACIES AND RELATED STRUCTURES, CENTRAL WEST GREENLAND.

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The geological development of the West Greenland rifted margin is closely related to the opening of the Labrador Sea in Tertiary time. Onshore central West Greenland the basaltic succession shows three very distinct basaltic facies; subaerial basalts, subaqueous pillow breccia basalts and hyaloclastites. Offshore the basaltic succession can be divided into different seismic facies, which partly can be related to the basaltic facies onshore. Structural studies onshore Nuussuaq peninsula has revealed a distinct pattern in the exposed part of the Lower Tertiary basaltic formations. The orientation of the lava flows, hyaloclastites, faults, dikes and joints shows a complex systems which can be divided in at least three directions. On the seismic data offshore it is possible to interpret some of the same directions of the lava flows and fault systems and it is possible to relate the structural pattern to the rifting phase of the opening of the Labrador Sea.

RIFT OF ADEN GULF: OBLIQUE RIFTING AND TRANSITION BETWEEN CONTINENT AND OCEAN LITHOSPHERE

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The rift of Aden gulf, located between Arabia, Somalia and Africa plates, was generated during the westward propagation of the Indian oceanic ridge. This rift displays the particularity to be located just at transition between an oceanic lithosphere and the continental domain oft Afars zone. The bathymetric data and the acoustic reflectivity, coming from the TADJOURADEN cruise, were used to map in detail the fault pattern and the volcanic activity. The rift, oriented N065 in the western part and N090 the central and eastern parts is formed by faults trending from N110 to N130, and corresponds to dextral oblique rifting. The extension direction, deduced from the fault histogram, gives a value of N038 5 from west to east, whatever the rift trend. The volcanism is mainly located at the easternmost part of the studied rift, where it fills up the axial rift. In the central and west segments, the volcanoes are gathered into swarms trending roughly perpendicular to the extension direction. The brittle/ductile transition, estimated from the inner grabens inside the rift, deepens from east to west: 4 km and 12 km respectively, that are typical values of oceanic and continental systems. An intermediate section of the rift displays heterogeneous depth values, indicating the mechanical transition between the two lithospheres. These results are discussed in terms of mechanics of rift propagation.

THE SOUTH-EAST GREENLAND VOLCANIC RIFTED MARGIN

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Four crustal seismic transects (combined wide-angle and vertical incidence data) across the East Greenland volcanic rifted margin provide an image of the spatial and temporal variation in margin structure and early Tertiary igneous crust as a function of distance from the Iceland hotspot track (Iceland-Greenland Ridge, IGR), where the igneous crustal thickness is a nearly uniform 32-36 km. In the proximal zone, a crustal thickness at breakup of up to 30 km decays gradually, over about 10 m.y., to 9-km-thick oceanic crust. In the distal zone we see a rapid decrease in magmatism from 17-18 km during breakup (55 Ma) to 9-10 km at 51 Ma. These results suggest a thin initial thermal anomaly in the distal zone, diminishing rapidly to a narrow region (~ 150 km) of influence for plume stem. The oldest igneous crust shows a thick, subaerially deposited, seaward-dipping reflector sequence (SDRS) with a smooth basement surface, widening onto progressively younger crust northward towards the IGR, which shows SDRS all across to Iceland. The oceanward termination is marked by a hummocky basement reflector, created by the rapid subsidence of the spreading ridge below sealevel. Seawards a smooth basement surface, interpreted to represent continued high lava productivity after the rift subsided sufficiently deep for longer flows to be possible. An apparently synchronous termination of this second wedge/smooth basement at 48-49 Ma is observed, possibly related to the establishment of rift tectonism.

PRESTACK DEPTH-MIGRATED IMAGES OF DETACHMENT FAULTING: THE H-REFLECTOR, IBERIA ABYSSAL PLAIN

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The "H-reflector" is a high-amplitude, subhorizontal reflector in the vicinity of Ocean Drilling Program Sites 900, 1067 and 1068 in the southern Iberia Abyssal Plain. In 1995 we acquired a series of intersecting deep multichannel reflection profiles which allow the geometry of this reflector to be defined in three dimensions. We present interpretations based on prestack depth migrations of these profiles and velocity models from a wide-angle seismic experiment in the same region. Our profiles show that H is sheet-like in shape and dips northward at ~10° towards Galicia Bank. At its southern limit, H rises close to acoustic basement. Above H, in both margin-parallel and margin-normal profiles, we observe fault-bounded crustal blocks overlain by triangular packages of syn-rift sediments. The apparent along-margin component of extension may be attributed either to the northward propagation of the late Jurassic early Cretaceous rift between Iberia and North America, or to local rotation of crustal blocks about a vertical axis due to along-strike variations in the degree of crustal extension.

A DETACHMENT FAULT IN 3-DIMENSIONS? : SEISMIC REFLECTION STUDIES OF THE H-REFLECTOR, NORTH IBERIA ABYSSAL PLAIN

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Simple shear as a model for rifting on passive continental margins has been applied to the Iberia Atlantic margin to explain strong, low-angle reflectors as major crustal detachment faults. We examine recently acquired deep seismic reflection profiles showing the H-reflector in the northern Iberia Abyssal Plain (IAP), adjacent to Galicia Bank. Pre-stack depth migration of intersecting lines includes a margin-parallel profile with which we constrain the sheet-like nature of H and which provides strong supporting evidence of the reflector as a major tectonic boundary. In this profile, H dips at ~10° northward toward Galicia Bank, and the profile defines its southern extent where it rises into the upper crust. Above H, the typical extensional features of fault bounded blocks of crust overlain by triangular packages of syn-rift sediments are identified, in both margin parallel and margin-normal sections. An along-margin component of extension is unlikely to be due to the later tectonic history, principally compression during the Pyrenean and later Betic orogeny. It may be attributed to either the northward propagation of late Jurassic/early Cretaceous rifting (unzipping) of Iberia and North America, or the rotation of crust around a vertical axis related to a disparity in the degree of extension between the IAP and Galicia Bank crust during rifting.

Structure and sediment distribution on the North Greenland continental margin and in the Fram Strait north of 80°N

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The separation of Greenland and Svalbard was completed approximately 10 Myr ago, when a deep water gate way to the Arctic Ocean, the Fram Strait, was formed. Between both margins a mid-ocean ridge system, the Knipovich Ridge, Molloy Rige and Lena Trough, build up. However, the structure of the margins and the Lena Trough north of 80°N were almost unknown due the lack of geophysical data.
In summer 1997 geophysical data across the Ob-Bank, Fram Strait and Yermak Plateau were acquired. The data show, that the Lena Trough is partly covered by sediments. The ridge has a small offset at 80° 30'N. In its central part water depths of more than 4000 m were found. The ridge valley is approximately 15 km wide.

The North Greenland shelf is characterized by shallow water depths of less than 50 m. The upper part of the sediments on the Ob Bank is eroded by glaciers and the seismic velocities of more than 4 km/s may indicate overcompaction of the material. Wide angle data indicate that the sediments are up to 8 km thick. First results of the expedition will be presented.

STRUCTURE OF THE GALICIA MARGIN PERIDOTITE RIDGE

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The Galicia Bank exposes on its western slope a peridotite ridge covered to the north by a basaltic apron and cut by few doleritic dikes. To the south, it consists dominantly of serpentinized peridotites with few dioritic levels but also comprises a 600m thick sequence of massive gabbros of limited NS surface. In the gabbro area, peridotites are covered by chlorite-bearing schists that chemically derived from differenciated gabbros formed 122My ago (U/Pb datations). The whole is locally overlained by a tectonic breccia comprising peridotite and granite blocks.
HT low-stress plastic deformation structures are ubiquitous within the peridotites but rare within the massive gabbros. But toward the top of the ridge, the peridotites and dioritic levels display high-stress HT ductile deformation structures, locally overprinted by LT ductile structures as well observed in the chlorite-bearing schists and in some peridotites. In the uppermost levels just beneath the tectonic breccia, late cataclastic structures are common.
The evolution of the physical conditions of deformations evidenced from base to top of the ridge let us believe that it well illustrates thinning mechanisms occurring in a continental lithosphere during stretching. Unfortunetely, the kinematics record do not fit well for use because of local dismembering of the studied outcrops.

THE SOUTH-EAST GREENLAND RIFTED MARGIN: A Record of Plume Impact and Later Continental Rupture

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Uplift and glacial erosion of the Southeast Greenland rifted margin provides unique access trough field investigations and offshore drilling to sample the geological record of continental break-up along a volcanic rifted margin. The earliest basaltic magmatism related to breakup is around 61 Ma old and very similar in age to the initial North Atlantic early Tertiary magmatism in West Greenland, the Faeroes and the British Isles. It is interpreted to reflect rapid impact and lateral spreading of the Iceland plume below the North Atlantic continental lithosphere. Final breakup took place around 56 Ma and was associated with a major increase in magmatic fluxes including: Up to 7 km thick flood basalts overflooding the continental margin and formation of new igneous crust 18 - 35 km thick along subaerially exposed spreading ridges. Observations from drill cores and crustal seismic velocity structure of the new igneous crust are consistent with an average contnent of 13- 15 percent MgO and 50 percent SiO_2 and ca. 17 percent partial melting suggesting a mantle temperature anomaly of 100-150°C during break-up. Observed magmatic fluxes seem too high to be explained by passive upwelling and cornerflow below the developing rift, but may be explained by a model involving mainly lateral flow within a thin sheet of plume mantle towards the rift zone and circulation of most of this through a relatively shallow melting zone.

FORMATION OF ATLANTIC VOLCANIC MARGINS AND EPISODES OF INTENSIVE PRODUCTION OF OCEANIC CRUST IN THE ATLANTIC

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We can demonstrate that nearly 70 % of the Atlantic rifted margins are volcanic margins, characterized by a more than 5 km thick and about 100 km wide wedge of seaward-dipping reflectors in upper crustal levels comprising extruded lavas.

The formation of volcanic margin follows a common evolutionary model including a brief, transient event of voluminous volcanic activity. Transient volcanic events occurred in the Bathonian, the Hauterivian through Barremian, Paleocene and early Eocene.

We observed also systematic and isochronous changes in the seismic images of Cretaceous-aged oceanic crust of the Atlantic. This observation suggests, that regionally warm mantle episodes can better explain for the origin of the volcanic margin instead of the hot spot and plume head models.

SEISMIC IMAGES OF 3-D VARIATIONS IN THE OCEAN-CONTINENT TRANSITION OFF IBERIA NEAR ODP LEG 149 AND 173 DRILL SITES

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We present combined MCS reflection and wide-angle refraction data across the ocean-continent transition off Iberia near ODP Leg 149 and 173 drill sites. Two E-W and four N-S migrated MCS profiles are converted to depth using velocity models from coincident wide-angle profiles. These profiles show consistent variations in velocity and reflectivity within the OCT in both N-S and E-W directions. In the E-W direction, the OCT is bounded by two main zones. The western zone comprises several N-S ridges where serpentinized peridotites have been drilled. The eastern zone consists in the north of stretched continental fault blocks, underlain by an "S- like" reflector that our velocity model suggests is a contact between stretched continental crust and serpentinized peridotite. Near Site 900, the continental crust has been cut by a diapiric structure, which may explain the variability of nearby basement samples. Towards the south, basement fault blocks disappear into a transparent layer of high velocity gradient, suggesting the presence of highly serpentinized peridotite. These patterns indicate that the OCT consists of a complex 3-D structure, in which thinned continental crust has been underlain and intruded by serpentinized mantle with little or no generation of oceanic crust.

SEISMIC VELOCITY STRUCTURE ALONG PROFILE IAM-9, SOUTHERN IBERIA ABYSSAL PLAIN

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We present results from a 340-km wide-angle seismic line across the Iberia Abyssal Plain which extends from the continental shelf to oceanic crust marked by seafloor spreading magnetic anomalies. West of a set of overlapping peridotite ridges, we find a typical oceanic crustal velocity structure with a crustal thickness of ~ 6 km. Beneath and for the peridotite ridges and in the ocean-continent transition zone, velocities increase from ~ 5 km/s to ~ 7 km/s in the upper 2-3 km of the basement. In the 2-3 km below this layer, velocities of 7.3-7.6 km/s are observed. This structure does not resemble either continental or oceanic crust. A thick layer of low velocity gradient and velocities between 6 and 7 km/s, typical of continental crust, is only observed where the crust thickens towards the continental shelf. Wide-angle or vertical Moho reflections are not seen in the transition zone. We interpret the upper high-gradient layer as upper mantle material which has been unroofed tectonically and serpentinised 20-100% by vigorous hydrothermal circulation, and the deeper layer to be 10-20% serpentinised peridotite. We find no evidence that the basement in the transition zone has been formed by seafloor spreading.

INVESTIGATIONS OF CONTINENTAL BREAKUP WEST OF IBERIA. NEW PERSPECTIVES ON RIFTING AND DRIFTING.

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Seismic studies, coupled with results from drilling, of the west Iberia rifted margin provide new constraints on the nature of the ocean-continent transition. The discovery of broad (up to 100 km) expanses of partially serpentinised peridotites and the imaging of related detachment faults is particularly important. Serpentinised peridotites are also an important component of oceanic crust formed at slow-spreading rates, where the classic pillow-lava/sheeted dike/gabbro stratigraphy may not apply. At these spreading rates, magmatism is intermittent and spreading may be by a combination of magmatic and amagmatic extension, the latter represented by large-scale faulting. Prestack depth migration of seismic profiles over old oceanic crust reveals the presence of deep-rooted and relatively low-angle normal faults: such structures may have exhumed the deep crust and mantle exposed at the seafloor. The importance of such structures in the formation of oceanic crust indicates that slow-seafloor spreading is similar to rifting leading to continental breakup at "non-volcanic" margins such as West Iberia. The similarity between the process of final rifting and slow-spreading may explain the difficulty in locating a boundary between continental and oceanic domains.

STRUCTURE OF THE GALICIA INTERIOR BASIN

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The continental margin off west Iberia is a non volcanic margin formed during the rifting between Iberia and New Foundland that led to the opening of the Atlantic. Offshore NW Iberia, between a narrow shelf and the Galicia Bank (GB), is the NS trending Galicia Interior Basin (GIB). This is failed rift whose inception ocurred in the Late Triassic but experienced later extension during Late-Jurassic to Early-Cretaceous. Final continental breakup took place west of the GB in late Aptian.
The MCS data provide two cross sections that run from the continental shelf through the GIB up to the Bank.The GIB has a symmetrical structure of tilted blocks bounded by down to the basin normal faults. Fan shaped sedimentary units infill half-grabens between these tilted blocks, indicating that were deposited in the Valanginan during the main extensional phase. The sedimentary unit above shows slight faulting, indicating that was probably deposited when GIB was subsiding and the main extensional activity was concentrated to the west. A latest Aptian regional uncomformity marks the continental breakup. Towards the GB the tectonic style changes consisting of tilted blocks dipping seawards. Overlaying sediment are cut by the breakup uncomformity. No important extensional tectonic activity is observed in sediment younger than Aptian. In the northern cross section a possible detachment fault deepens towards the basin and suggests a detachment level for the down to the basin faults of the GIB. West of the detachment fault most blocks are rotated seawards. In the southern section no detachment fault has been identified.

CONJUGATE MARGINS OF THE LIGURIAN SEA, NORTHWESTERN MEDITERRANEAN : DEEP STRUCTURE AND EVOLUTION

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We present new results on the crustal geometry of the Ligurian Sea from multichannel seismic (MCS) and wide-angle seismic (WAS) data acquired during MALIS cruise (1995). The Ligurian basin differs from Atlantic-type oceans by a quick and short Oligo-Miocene opening, giving birth to narrow and segmented conjugate margins with contrasted geometry and structure which are described here. The Provençal-Ligurian margin (PLM) is generally composed of two ~15 km wide tilted-fault blocks, whereas the Corsican margin depicts shorter ones below volcanic rocks. Over 50 km along the eastern PLM, we observe highly reflective, parallel, landward dipping reflectors at the base of the crust between 8 and 11 km depth. We improve the basement and Moho geometry thanks to a forward modeling of WAS data. The top of the basement deepens down to 9 km depth in the basin and the Moho rises abruptly from 21-26 km depth under the upper slope to 13-15 km in the basin. On the Corsican margin, the rough geometry of the Moho proposed here allows us to precise the opening style of the Ligurian sea. Finally, we evidence a huge lowstand system tract (slope fan) connected to the salt layer at the foot of the margins, witness of the Messinian salinity crisis. Deformation at the base of these erosional deposits and other current tectonic clues in the PLM and the basin confirm the recent compressive reactivation of the easternmost foot of the PLM linked to the on-going convergence between Europe and Africa.

ELASTIC PROPERTIES OF SUBAERIALLY EMPLACED BASALTS ON RIFTED MARGINS: THE IMPORTANCE OF CLAY ALTERATION

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Voluminous, subaerial basalt complexes are commonly constructed during continental breakup. Wireline log data from boreholes along the Atlantic and western Australian volcanic margins reveal a characteristic P-wave velocity (Vp) pattern in these complexes, with cyclic low-velocity (Vp ~ 2-3 km/s) and high-velocity (Vp ~ 5.5-6 km/s) intervals. These large changes in velocity reflect morphological variations within individual lava flows of 1-50 m thickness. Ocean Drilling Program Hole 990A on the SE Greenland margin penetrated 14 subaerial lava flows with very high core recovery. More than 1000 laboratory Vp measurements were done on the core, giving an average sampling interval of about 0.15 m. Petrological, geochemical and x-ray diffraction analysis of 18 samples from the upper and middle part of three lava flows show a good correspondence between Vp and the degree of alteration. The low-velocity intervals are entirely altered to clay minerals (smectite) and iron-hydroxides, while the high-velocity interiors are fairly fresh, crystalline basalts. Intermediate degrees of clay alteration are associated with intermediate velocities and high magnetic susceptibility values. The rapid upward decrease in velocity is interpreted to reflect the transition from a crystalline grain-supported to a clay-supported rock matrix. The elastic properties of clays may thus have to be considered with an equal importance in basaltic terrains and clastic sedimentary basins when studying elastic wave phenomena in these settings.

MAGNETIC STUDIES IN THE IBERIA ABYSSAL PLAIN: SOURCE BODY CHARACTERISATION ACROSS THE OCEAN CONTINENT TRANSITION

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Inversions, forward models and series analysis of magnetic anomaly signals, in profile and chart form, reveal significant differences in source bodies across and parallel to the margin in the Iberia Abyssal Plain. A strong partition of magnetic source types is defined parallel to the margin and coincident with a peridotite ridge: to the west basement is strongly magnetized, and to the east, it is generally more weakly magnetized with some regions of higher magnetization. The former is interpreted as typical seafloor spreading oceanic crust, the latter as transitional basement with at least one local occurrence of oceanic crust or strongly serpentinized transitional basement. The transitional basement is interpreted as either weakly serpentinized mantle peridotite, intruded mantle peridotite or intruded thinned continental crust. The peridotite ridge itself is generally weakly magnetic. Patterns of source solutions suggest most sources strike approximately N-S across the transitional region and may lie at depths greater than the top of basement. However, this zone might also be subdivided; a western zone with many linear source solutions, and an eastern zone lacking in source solutions. This may suggest variations in magnetic source generation, through time either as intrusions or serpentinization contrasts, or the heterogeneity of the original peridotite.

SEAWARD-DIPPING REFLECTOR SEQUENCES AT SOUTH ATLANTIC PASSIVE MARGINS AND THE SOURCE OF MAGNETIC ANOMALY G

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DSDP/ODP drill holes into several seaward-dipping reflector sequences (SDRS) show that they are composed of a great number of thin basalt flows that were emplaced subaerially or under shallow-water conditions. Drilling results also show that the basalts possess a high natural remanent magnetization (NRM). NRM values for the Vøring Plateau basalts (core samples of ODP Site 642E) give a mean (effective) magnetization of 4.0 to 4.5 A/m for the whole volcanic section. A magnetic model using this magnetization for the SDRS on the Vøring Plateau gives an excellent fit to the observed magnetic anomalies. Reflection seismic data from the South Atlantic margins off Argentina and Namibia/South Africa show SDRS that coincide with the magnetic anomaly G. Magnetic modeling confirms that the SDRS are the source of anomaly G. On some lines were SDRS have been identified on seismic records, a distinctive magnetic anomaly does not exist. The following mechanism explains the high and stable NRM of SDRS and predicts that strong magnetic anomalies should be associated with them when they were extruded within one polarity interval:

- Single basalt flows that cool quickly after their subaerial emplacement acquire a strong and stable thermoremanent magnetization.
- The successive accumulation of single flows results in the formation of thick wedges of SDRS having NRM intensities that are typical for the much thinner pillow basalt layer of 'normal' oceanic crust.

THE CONTINENT/OCEAN BOUNDARY OF BAY OF BISCAYE

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The Armorican Basin is located at the foot of the northern non-volcanic rifted margin of the Bay of Biscaye. South of this very deep basin, the continent-ocean boundary was located on a large negative magnetic lineament linked to a long basement ridge, the North Biscaye Ridge. We will present interpretations from new deep multichannel seismic reflection profiles (NORGASIS cruise, 1994) crossing the Armorican continental margin, the Armorican Basin and the North Biscaye Ridge :

- Beneath the margin, the continental crust is thinned mainly due to the vanishing of the layered lower crust.
- Within the northern part of the Armorican Basin, the thinned upper continental crust lies directly on a bulged mantle. Internal low frequency reflectors appear within this mantle, which deep oceanwards and are truncated by the overlying layer.
- Adjacent to this northern part, the acoustic basement is deeper and hardly defined. A major tectonic fault, within the upper mantle layer, separates deeply this 30 km large domain from the previous one.
- Further south, the oceanic domain appears shallower, marked by an irregular and diffracting surface and linked to the North Biscaye Ridge which was reactivated by a main compressive Eocene deformation.
- South of this basement ridge, which appears to be oceanic, acoustic basement is non deformed and subsided.

SE47 Structure and composition of oceanic lithosphere

Convener: Danobeitia, J.

03 Processes of crustal accretion at mid-oceanic-ridges

Convener: Escartin, J.
Co-Conveners: Canales, J.P.; Cochran, J.R.

REVIEW OF THE OCEAN-CONTINENT TRANSITION (OCT) IN THE SOUTHERN IBERIA ABYSSAL PLAIN, WEST IBERIA MARGIN

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Since 1986 seven research cruises and two ODP drilling legs have acquired data in the southern Iberia Abyssal Plain. Charts of basement relief and magnetic anomalies show margin-parallel highs and lows west of a margin-parallel peridotite ridge (PR). Although new seismic velocity models and modelling of sea-surface and deep-towed magnetometer profiles are consistent with seafloor spreading beginning here during anomaly M3 time recent drilling did not core rocks characteristic of oceanic crust. East of the PR the magnetic anomalies are mostly smaller but often sub-parallel to the margin, basement magnetisation is weaker and basement relief is not strongly elongated. Tops of magnetic source bodies may lie as deep as 3 km into basement. Also east of the PR multichannel seismic reflection profiles show either 1) fault blocks that decrease in size oceanward and are underlain by listric faults (drilling at 3 sites strongly suggests these are blocks of continental crust) or 2) a deeper region of usually lower relief, sometimes characterised by a seismically unreflective 1-2.5–km–thick top basement layer of probable strongly serpentinized peridotite. Evidence of synrift magmatism is scarce or ambiguous. Development of the OCT was dominated by tectonism over a wide range of scales, including high- and low-angle lithospheric faults.

COMPARISON OF CRUSTAL STRUCTURE BENEATH A ROBUST AND A NON ROBUST REGION OF THE SEPR

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In 1991, a two-ship multichannel and OBS (Ocean Bottom Seismometers) experiment (TERA) was conducted on the Southern East Pacific Rise (SEPR) at 17°20'S. The rise axis is broad and inflated, the magma sill is very shallow and submersible observations provide evidence for recent eruptions, suggesting active magmatism. Common Depth Profiles (CDP) and Expanding Spread Profiles (ESPs) were deployed while airgun shots were recorded by 4 OBSs. We will present a combined 3D tomographic inversion of P-wave arrivals.

During the MELT experiment, OBS data were also collected 150 km north of the TERA area. The 350 km seismic profile of the northern MELT array crossed the SEPR at 15°55'S near a small overlapping spreading center (OSC). This part of the rise axis is narrow, exhibits a triangular cross section and no magma chamber sill is seen with seismic reflection methods. A total of 2515 vertical component Pg, PmP and Pn traveltime arrivals were picked along 5 record sections.

We will compare the ridge structure below these two very different regions of the southern SEPR through inovative tomographic techniques. Preliminary results already indicate that crustal thicknesses are similar in the two regions. These observations could argue against magma supply models for ridge segmentation in which magma supply is enhanced beneath shallow portions of the ridge crest and is depleted at the ends of a segment near OSCs or other discontinuities.

SEGMENT-SCALE CRUSTAL STRUCTURE VARIATIONS WITHIN THE RIFT MOUNTAINS OF THE MID-ATLANTIC RIDGE (35°N)

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We present the results from combined forward modeling and 2D tomographic inversion of wide-angle seismic reflection data recorded on ocean bottom hydrophones along the western rift mountains of the Mid-Atlantic Ridge (MAR) at 35°N. The study area is part of the *Bullseye Seismic Experiment* (Oct.-Nov. 1996) over two MAR segments, the OH-1 between the Oceanographer Fracture zone (OFZ) and the 34°30'N non-transform offset (NTO1), and OH-2 between NTO1 and NTO2 at 34°N. The objectives are: (1) determining variations in seismic crustal structure as the crust is transferred from the axial valley to the rift mountains, and (2) analyzing along-axis variations in crustal structure from Inside to outside corner, and between segments across an NTO. The record sections show good signal-to-noise ratios up to 60 km offsets, in some cases op to 80-100 km ranges, allowing resolution of the P-wave velocity structure up to 80 km b.s.f. In the western rift mountains of OH1 the velocity structure in the upper 3 km of the crust is relatively homogenous along-axis. The lower crust (3-6 km b.s.f.) at the center of OH1 is characterized by velocities of 7.0-7.2 km/s. At the base of the crust we find anomalous velocities (7.2-7.5 km/s) intermediate between typical lower crust and upper mantle that we interpret as a transitional Moho. This transition thins towards the segment ends indicating crustal thinning consistent with gravity observations. Although a very thin mafic crust may be present beneath NTO1 and OFZ, seismically it is associated with low P-wave velocity (<6.0 km/s) at 3 km depth. The low velocity and linear velocity gradient of both discontinuities may reflect high degree of aeration and fracturing of the crust and uppermost mantle.

Crustal thickness, regional axial depth and melting parameters at slow spreading mid-ocean ridges.

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This paper discusses the effect of having a slow spreading rate on the relation between regional axial depths, and melting parameters such as melt thickness, mean rate of melting (mean F, that can be translated into predicted Na8.0 content of basalts using the relation proposed by Klein and Langmuir, JGR, 92, 1987), mean pressure and maximum rate of melting. Compared to what happens at faster spreading rate, these relations should be perturbed by enhanced conductive cooling in the mantle beneath the ridge, and by the incorporation of mantle-derived serpentinized peridotites in the crust. The model used assumes that regional axial depths reflect isostatic compensation and that mantle and melt flow beneath the ridge are passive, and calculates melting parameters in the same way as in Langmuir et al. (AGU Geophys. Monogr. 71, 1992). As already shown by Bown and White (EPSL, 121, 1994) and contrary to predictions by Reid and Jackson (Mar. Geophys. Res., 5, 1981), melt thicknesses and mean F appear to be mostly controlled by mantle solidus temperatures. They vary very little with spreading rate, except at full rates slower than about 1.2 cm/yr. The incorporation of serpentinized peridotites in the crust affects the relation between melt thickness (M) and regional axial depth (Z): for a given value of M, Z decreases as the proportion of serpentinized peridotites in the crust increases. These predictions are discussed in view of published data on regional depths, seismic crustal thickness and basalt major elements composition at slow and ultra-slow ridges.

GEOLOGICAL SETTING OF THE AREAS OF HYDROTHERMAL ACTIVITY ON THE KNIPOVICH RIDGE.

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Two areas of hydrothermal activity were revealed based on the CTD data on the ultra-slow spreading Knipovich Ridge in the North Atlantic during the R/V Logachev cruise in 1996. Both areas are located near the ends of the same tectonic segment, at 76°47'N and 76°38'N. Zones of non-transform offsets and adjacent regions of valley floor are characterized by bathymetric highs and recent volcanic activity whereas in the central part of the segment the valley floor is relatively subsided and mostly buried by thick sediment cover. Bathymetric high associated to northern end of the segment is manifested by the 120-m high transverse terrace of volcanic origin. Its surface is composed of young pillow and platy basalts without visible sediment cover. Southeastern flank of the terrace is controlled by fault scarp parallel to the spreading axis with young lava breccias at its base. The hydrothermal activity indicators are detected at the intersection of this fault (which apparently was a magma conduit) and transverse fracture zone connected with fault scarp series on the rift valley walls. Structural pattern of the southern end of the segment is determined by the 500-m high axial volcanic ridge situated asymmetrically to the median valley floor. It lies close to the eastern valley wall and converges obliquely to intersect the wall just north of the non-transform offset. According to side-scan sonar data, the youngest unsedimented basalts of the axial ridge are associated with lower part of its eastern slope and with adjacent linear deep. Sediment cover is absent also within the scarp of eastern valley wall that suggests its recent tectonic activity. Near 76°38'N the rift valley is crossed by the transverse tectonic dislocation manifested by small lateral offsets of the valley wall scarps and by change in configuration of axial volcanic ridge. The hydrothermal activity is related to the intersection of the along-axial fault, which controls the region of recent volcanic and tectonic activity, with zone of transverse tectonic dislocations.

RIFT PROPAGATION ON THE SOUTHEAST INDIAN RIDGE

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The Southeast Indian Ridge (SEIR) is influenced by the Amsterdam hotspot and by the deep, cold Australian-Antarctic Discordance (AAD). Along the SEIR, all non-transform ridge offsets of greater than a few km are propagating toward the AAD, driven by gradients in axial bathymetry and along-axis asthenospheric flow associated with the gradient in upper mantle temperature. The morphology of these propagating rifts (PRs) varies systematically with distance from the center of the AAD. PRs near 91°45'E, 128°E and 131°E where the ridge has an axial high take the form of large propagating OSCs. At the 95°45'E PR, the ridge axis high is less well developed, and the ridge axis plunges 400-550 m as the rift tips are approached. Rotated morphologic fabric is observed between the rift tips and along the inner pseudofault. The axis is characterized by a shallow valley near PRs at 111°E and 112°45'E. A localized transform-like shear zone is developed between the rift tips at these rifts. 'as the propagating ridge advances beyond the shear zone, an elevated (by 500-1000m) region is developed ahead of the rift. Rotated fabric is not observed between the rift tips where there is a bathymetric high. Ridge propagation occurs episodically resulting in a sinuous outer pseudofault with the uplift ahead of the rift tip preserved along the outer pseudofault. The retreating rift fails in discrete jumps so that the inner pseudofault is marked by a series of pairs of abandoned rift tips and topographic highs. Geochemical anomalies associated with the PRs appear to correlate inversely with the magma supply.

COMPARING CRUSTAL MELT AT THE EAST PACIFIC RISE AND THE JUAN DE FUCA RIDGE

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We present results from geophysical experiments to estimate the melt distribution at three OSC locales: 9°48'N on the East Pacific Rise (EPR), between 44°37-40'on the Cleft segment of the Juan de Fuca Ridge (JdFR) and between 46°13-25'N on the Coaxial segment of the JdFR. Measurements of the seafloor deformation under pressure forcing by ocean surface (water) waves, known as seafloor compliance, are modeled to estimate the shear velocity structure of the underlying crust. Within the EPR at 9°48'N, shear velocities are low above and below the shallow (1.4 km beneath the seafloor) melt lens. In addition, a second melt lens is detected at approximately the depth of the crust-mantle interface. Low shear velocities within the JdFR Cleft segment are centered 3 km beneath the seafloor, and are surrounded by normal shear velocities. Low velocities are not detected near to the Coaxial segment axis, but crustal shear velocities decrease to the west of the axis, reaching a minimum 3 km beneath the north rift zone of Axial volcano. The EPR shear velocities are consistent with 2-15% melt in the lower crust, connecting melt at the bottom of the crust to the shallow melt lens. Within the Cleft segment and the north rift zone of Axial Volcano, the top of melting is deeper than at the EPR, and this melt may not be connected to a mantle source by steady-state percolation. There is no evidence of melt within the imaged section of the Coaxial segment axis.

THE PETROLOGICAL PARAMETERS AS THE INDICATORS OF THE MID-OCEAN RIDGES GEODYNAMICS

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The distribution of petrological parameters (temperature, pressure, water and MgO content and K_2O/TiO_2 ratio) along axial zones of MAR, EPR and Galapagos Spreading Center has been estimated for about 14 000 abyssal glass compositions (Smithsonian Catalog; Niu & Batiza data, 1993; Sushevskaya et al, 1990-1996 and our original data). The obtained results and data about distribution of the hydrothermal fields (Rona & Scott, 1993 and other sources) were plotted on bathymetry (CD-ROM,NGDS, No 1093A27001), gravimetry (Sandwell D.T.&Smith W., 1992) and compared with modern models of ridges geodynamic segmentation. This study allows to discover new features of the magmatism stability in the connections with tectonic conditions and mantle movements for zero-age period of ridge formation. It was found that all the hydrothermal fields are strongly localised near the deep seated and long existed boundaries between tectono-magmatic provinces of ridges. Very specific new tholeiite basalt type with anomaly high water content localised near hydrothermal fields. The study of endogenic and exogenic processes interaction in ligt of hydrothermal field origin is discussed.

HOTSPOT EFFECTS ON FAULTING AND TECTONIC STRAIN ALONG THE GALAPAGOS SPREADING CENTER

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We analyze multibeam bathymetry along the axis of the Galapagos spreading center (GSC) to determine variations in characteristic fault spacing and height, and in tectonic strain. Spreading rate at this section of the GSC varies between 44 and 65 mm/yr, and the Galapagos hotspot is located ~200 km to the S of the center of the study area. These conditions are ideal to study the compting effect of spreading rate and hotspots on faulting processes of the lithosphere. Faults are interpreted from topographic, slope and curvature maps, and from backscatter images. The measured fault spacing and height are used to calculate the tectonic strain, assuming a constant fault dip angle. Fault spacing decreases as spreading rate decreases. Tectonic strain is minimum near the hotspot and increases away from it. This trend is also observed in the seafloor roughness. Fault height shows dependence on both spreading rate and hotspot distance. The dependance of fault spacing on spreading rate may indicate that this is the primary control on lithospheric thickness, with weak hotspot influence on the shallow lithosphere. Then enhanced magmatic supply near the hotspot increases magmatic strain, resulting in both low tectonic strain and roughness.

GEOPHYSICAL STUDY OF A YOUNG SPREADING RIDGE AND ITS SEGMENTATION: THE WESTERN GULF OF ADEN

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Oceanic spreading processes at slow spreading ridges have been much refined in the last ten years. The seafloor spreading appears as a 3D process and the axis segmentation illustrates the along-axis alternance of magmatic and tectonic activity. Among unresolved questions are the time dependant evolution of this segmentation on large periods (> 10 Ma) as well as its origin.
The study of the western Gulf of Aden ridge allows to infer for the crustal structure and the segmentation of a recent and oblique spreading ridge, as well as the thermal influence of the close Afar hot spot. Complete Bouguer anomalies have been computed in this area using data from the *Tadjouraden* cruise (N/O L'Atalante, 1995). Their interpretation and inversion show three distinct areas from East to West. The eastern domain is characterized by rather well established oceanic spreading, whereas the western end is still dominated by pure crustal thinning similar to continental rifting. The central area consists of a transition between pure tectonic stretching and actual magmatic spreading. The segmentation of the axis is essentially a tectonic one and consists of a succession of independant oblique basins overlying stretched crust, where magmatic activity is still rare. Thus this kind of segmentation can appear as a seaward continuation of continental rifting patterns ! ! possibly evolving later to the s egmentation observed at slow ridges with increased magmatic activity.

ACCRETION OF OCEANIC LAYER 3 AT THE VERY-SLOW SPREADING SW INDIAN RIDGE, OCEAN DRILLING PROGRAM HOLE 735B.

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Hole 735B is sited in an uplifted block of layer 3 gabbro, which formed 11 Ma ago at the very-slow spreading SW Indian Ridge. During ODP Leg176 (Oct.- Dec. 1997) the hole has been deepened from 500m to 1508m below sea floor. Overall core recovery is a high 86%. On the basis of the chemical composition of some 400 samples, five main chemical/petrological units can be distinguished. The thickness of these units varies from 200 to 400m. Each unit exhibits an internal differentiation from relatively primitive troctolite or olivine gabbro at the bottom to more fractionated Fe-Ti rich compositions at the top. Moreover, each unit experienced an individual structural, metamorphic and alteration history. These main units are in turn intruded by numerous bodies of FeTi-oxide-rich gabbros. These rocks crystallized from evolved residual liquids, which migrated from elsewhere as a result of compaction attending crystallisation and tectonic activity. The picture emerging is one of crustal accretion through intermittent magmatic pulses. The main units represent the scale at which separate magmatic events add to the construction of oceanic crust at very-slow spreading ridge segments. There a very few, if any, indications for the presence of a steady-state magma chamber. Tectonic processes exerted a strong control on mineral/melt segregation and the migration of evolved residual melts.

STRUCTURAL EVOLUTION OF THE LOWER CRUST AT SLOW-SPREADING RIDGE : PRELIMINARY RESULTS FROM ODP LEG 176, SITE 735B, SOUTH WEST INDIAN RIDGE

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During Leg 176, over 860 m of gabbroic rocks (86.6 % recovery) have been cored from the lower ocean crust accreted at the very slow-spreading South West Indian Ridge (SWIR), 11 Ma ago. Thick intervals of the core (up to 150 m) are either isotropic or contain local domains with weak to moderate magmatic foliation, often overprinted by a weak, parallel crystal-plastic fabric. They alternate with shear zones of variable thickness (1 cm to 30 m) and intensity, developed under conditions ranging from hypersolidus to semibrittle. Numerous shear zones have a reverse sense of shear. Fe-Ti oxide gabbros are generally, although not systematically, associated with shear zones. Brittle deformation results in hydrothermal veins, fault zones and extremely localised cataclastic zones of variable thickness, with unknown sense and magnitude of displacement. The intensity of deformation globally decreases downhole. Structural features at site 735B suggest that crustal accretion at SWIR is associated with localised deformation at conditions ranging from magmatic to low-temperature cataclastic. Melt intrusion and deformation are likely episodic processes that occur either separately or synchronously.

DIFFERENT PERIODS OF HYDROTHERMAL ACTIVITY AT THE MESO ZONE, CENTRAL INDIAN RIDGE (CIR).

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Hydrothermal activity is fairly well documented from most mid-ocean ridges, but there is only one hydrothermal area known from the Central Indian Ridge (CIR) so far. The fossil tectonized deposit, referred to as MESO zone, is situated in the 4th ridge segment of the CIR, north of the Rodriguez Triple Junction, near 23°S. The mineral deposit is located in a water depth of 2850 m near the top of a neovolcanic ridge, which subdivides the central rift valley of the CIR over a distance of about 20 km. Hydrothermal precipitates occur as chimney relicts, as shallow mounds comprised of sulfidic material or as sediment colorations. Extinct chimney edifices are aligned along fissures and cracks running both parallel and vertical to the general strike direction of the ridge (N153°). Two locations in the northern part of the MESO zone, called Talus-Tips-Site, and two in the central part, called Sonne-Field were sampled. Age dating using $^{230}Th/^{234}U$ method show that the high temperature hydrothermal activity started possibly 140 ka ago at the Talus-Tips-Site. After a period of quiescence it was reactivated, around 52.5 ka for some thousand years. Another interruption for several thousands years occurred around 23 ka, whereas high temperature activity is detected southeastwards in the Sonne-Field (18±2 ka). The last high temperature hydrothermal event at the Talus-Tips-Site has been dated at 16±2 ka and terminates the activity at the Talus-Tips-Site. The formation of sulfides at the Sonne-Field, interrupted at about 16 ka, was reactivated 12.5±1.5 ka ago for a period of about 3 ka. This chronology will be compared to the one at MAR.

DETAILED NEAR-BOTTOM SIDESCAN OBSERVATION OF THE SOUTHWEST INDIAN RIDGE

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During October and November of 1997, scientists from France, United Kingdom, and Japan conducted a multidisciplinary geological and geophysical survey of the ultra-slow spreading Southwest Indian Ridge (half spreading rate of 0.7 cm/yr) under the auspices of InterRidge onboard R/V Marion Dufresne. Three areas were targeted specifically in which detailed near-bottom sidescan observation using Towed-Ocean Bottom Instrument (TOBI) and underway geophysical measurements including multibeam bathymetry, gravity, and proton and shipboard three-component magnetic data were made. We present the preliminary results of our analysis of TOBI sidescan data from one of the three areas, the third box, which is centered at 2755S and 6342E and where our coverage extends off-axis approximately to anomaly 2. According to the sidescan and multibeam bathymetric data, the general topography in this area exhibits a strong contrast between the northern and southern ridge flanks. An axial volcanic ridge which seems to be dominated with relatively fresh hummocky mounds and sheet flows appears to have propagated to the east. One of the most notable features is a large striated surface which is interpreted as a detachment fault, similar to mega-mullions described in the Atlantic. In addition to conventional sidescan sonar imaging, we also performed swath bathymetry analysis using phase angle differences among receivers mounted on the side of the deep-tow vehicle. Initial results show that high-resolution phase bathymetry is a powerful means of identifying faulted and volcanic terrains and constraining their geometric characteristics.

CRUSTAL STRUCTURE AND SEGMENTATION ON THE SWIR AT 66°E.

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A wide-angle seismic experiment over crust aged 0-7.5 Ma on the Southwest Indian Ridge at 66°E has imaged the structure of four adjacent ridge segments, and the three non-transform discontinuities between them. Two segments with complete coverage are 26 and 37 km long, significantly shorter than the 45-60 km averages reported for the MAR. The segmentation pattern is consistent with that inferred from bathymetry and magnetic data. Crustal thicknesses vary from 3-6 km at segment midpoints, to 2-3 km beneath discontinuities, with a spatial average of 4.2 km. Since the seismic crust may contain some serpentinised mantle peridotite at very slow spreading rates, this value indicates that the maximum melt production at the ridge axis is considerably less than the 6-7 km typically observed at faster spreading rates. One segment shows 25% thinner crust (3.2 km average) at 1.5 Ma, suggesting that the melt production was reduced for a period of time, and may vary from one magmatic cycle to the next. Seismic Layer 2 is consistently 2-2.5 km thick, even across discontinuities, where a lower melt supply is inferred, and despite the outcrop of serpentinised peridotite, suggesting that Layer 2 depends on porosity rather than lithology. A near-zero Layer 3 thickness at segment discontinuities, and 2 km thickness at midpoints, suggests focussed upwelling and melt accumulation at depth beneath segment centres, with lateral melt migration towards discontinuities at upper crustal levels. Seafloor velocities vary from segment to segment (2.4-3.5 km/s).

CONSTRAINTS ON HIGH FREQUENCY ERUPTION DYNAMICS AT MOR'S FROM DOWNHOLE ELECTRICAL IMAGES.

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Crustal drilling and downhole measurements provide a high-resolution record of accretion processes at mid-ocean ridges, hence a unique method to describe eruption dynamics in a continuous fashion. As DSDP Hole 395A (Mid-Atlantic Ridge/MAR, 23°N) was re-entered during ODP Leg 174B, downhole images were recorded in 7.3 Ma old oceanic basement. The hole penetrates more than 500 m of lava accreted as a series of dm-scale volcanic cycles identified in the past from core petrological and magnetic records, and downhole measurements. At a higher frequency, the electrical images recorded during ODP Leg 174B reveal a higher frequency periodicity, with pillow thicknesses varying from 0.8 to 1.2 m, and increasing toward the end of lower frequency cycles. While the latter reveal changes in lava physical properties during accretion, the former could be due either to changes in magma supply or to time between eruptions. Pillow and flow geometries with paleoflow directions can also be derived from high-resolution images. Both low-frequency profiles and high-resolution images pertain to a structure accreted at slow-spreading rate along the MAR. Substantially different low-frequency record and thicknesses are obtained from ODP Site 504 accreted at faster rate along the Costa Rica Ridge.

SE47 Structure and composition of oceanic lithosphere

Convener: Danobeitia, J.

04 Collisional and transform plate boundaries and subduction zones

Convener: Henstock, T.J.
Co-Convener: Ranero, C.R.

LIFE CYCLES OF AXIAL VOLCANIC RIDGES: MORPHOLOGICAL COMPARISONS BETWEEN THE MID-ATLANTIC RIDGE AND THE REYKJANES RIDGE

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We have completed extensive mapping of axial volcanic ridges (AVRs) within four areas along the Mid-Atlantic Ridge (MAR), between the Kane and Atlantis fracture zones, and two areas along the Reykjanes Ridge (RR) at 58 and 60 degrees N, from high resolution (tens of meters) sidescan sonar data. Axial volcanic ridges (AVRs) are comprised of small-scale volcanic features including seamounts, hummocky linear ridges, hummocks and smooth-surfaced flows. By modelling eruption and cooling behavior of dikes and volcanic flows in this environment, we can make predictions as to the widths of dikes feeding different types of volcanic constructs, and the relative state of the spreading segment in the context of a magmatic/ tectonic life cycle. Comparisons of AVRs along the MAR with those of the RR allow us to examine the effects of the Icelandic hotspot on the morphology of volcanic constructs. Preliminary analyses suggest that the variation in volcanic morphology and fissure density between the MAR and RR is comparable to that observed between the four MAR areas studied. This suggests that the Icelandic hotspot does not have a significant influence on small-scale surface morphology. We present results of our analyses and examine their implications for life-cycle models of oceanic crust formation in which a magmatic phase of activity is followed by a tectonic phase.

HOW MANY MANTLE SOURCES INVOLVED IN FORMATION OF RESIDUAL PERIDOTITES FROM MAR BETWEEN 14 AND 16°N?

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Main goal of study presented is determination of geochemical types of mantle sources for magmatism beneath MAR between 14° and 16°N and reconstruction of different stages of recrystallization of residual peridotites from MAR segments examined. Large "Hess" Crust segment composed of non-homogenic geochemically peridotites exists in Western and Eastern Intersection 15°20'FZ and MAR. There are three main groups residual peridotites present at MAR regoin examined judging by geochemical data. The first one includes extremely depleted residual peridotites represented by harzburgites and dunites recovered at both Eastern and Western Ridge-Transform Intersection as well as at transform wall. The second one established at ERTI and presented by plagioclase bearing harzburgites characterized by mediate to low degree of melting and geochemical evidence for enrichment of mantle component is close to SHC (Sant Helena Component). The third one consists of Phlogopite bearing peridotites is most enigmatic peridotites among those recovered at 15°20' FZ not related genetically to volcanic and plutonic rocks are distribute at the MAR. These peridotites were present at rift valley wall north of WRTI only. Shortwavelength geochemical and isotope heterogeneity of mantle below MAR segment between 14° and 16°N exists.

EPISODES OF CONTRACTION AND EXTENSION ALONG THE EASTWARD PROLONGATION OF THE ROMANCHE FRACTURE ZONE, CENTRAL ATLANTIC OCEAN

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The Romanche Fracture Zone (RFZ), with its 900 km length, is the longest transform boundary in the Atlantic Ocean. Satellite gravity anomaly maps show that the scar of the RFZ continues eastwards from the ridge-transform junction to the coast of Africa. Four geophysical surveys have been carried out in 1992, 1993, 1994 and 1996 over the prolongation of the RFZ close to the ridge-transform junction. An area of c.a. 350 x 140 km was covered with the acquisition of about 1500 km of multichannel seismic reflection profiles. In addition, 13 dredging stations have been operated during three of the above mentioned cruises (1993, 1994 and 1996) and the collected samples allow a crude calibration of the stratigraphy of the area. Worth of note is the recovery of several samples belonging to sedimentary units ranging in age from Early Cretaceous to Eocene. Besides the Present transform valley sedimentary fill, seismic profiles show the presence of older sedimentary basins that were successively affected by variable amount of tectonic inversion. Faults with large extensional components are also well displayed and they appear to shape the present morphology of this segment of the RFZ. The geometry of the recognized structures and the stratigraphic data allow to propose a tentative tectonic evolution of the study area that have also implications on the kinematics of the entire RFZ.

SEISMIC REFLECTION INVESTIGATIONS IN THE NORTHERN ARABIAN SEA OFF PAKISTAN DURING SONNE CRUISE SO-122 (MAKRAN)

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During SONNE cruise SO-122 (MAKRAN), BGR performed geophysical investigations of the northern Arabian Sea off Pakistan. Multi-channel seismic reflection lines with a total length of 2927 km were collected in combination with magnetics, gravity, sediment echography and bathymetric swath measurements in a complex geological setting influenced by subduction and strike-slip motions.
The Makran accretionary complex has a sediment thickness of at least 5-7 s TWT. East of about 65°E, the base of the accretionary complex is clearly imaged and no bottom simulating reflector (BSR) is visible. Further to the west, a BSR is well developed, but no basement can be found on unprocessed data. The Oman Abyssal Plain consists of oceanic crust and contains the Makran trench and a volcanic structure called Little Murray Ridge. It narrows towards the east where the Makran accretionary complex meets the Murray Ridge and subduction changes to collision. Its 3-5 s TWT thick sediments are subdivided by a distinct unconformity. The Murray Ridge is divided by an asymmetric graben into a higher southern and a lower northern part. The graben may have been created by subduction of the Arabian Plate beneath the Eurasian Plate and simultaneous strike-slip motion between the Arabian and the Indo-Pakistanian Plate. An anticlinal structure in the north-east of the ridge may be a melange that continues onshore into the Bela-Waziristan ophiolite zone.

FIRST RESULTS OF SONNE LEG SO 123 - MAMUT

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During SONNE leg SO 123, geophysical investigations were performed at the Makran accretionary wedge and in the Murray Ridge area. They concentrated on wide-angle seismic measurements, coincident with existing seismic reflection data, and detailed bathymetric swathmapping. First results allow the following conclusions:

At the Makran accretionary wedge, a 7 km thick sediment layer rich in quartz (Himalaya turbidite and Makran sands) enters the trench. About 50% of the sediment is subducted together with the oceanic crust at an angle of 2 - 3°. The upper part is accreted frontally. A clear BSR can be recognized, extending into the oceanic basin of the Gulf of Oman. The morphology of the accretionary wedge is far more complicated than expected.

The Dalrymple Trough, a 2000 m deep depression filled with 5 to 7 km of sediment, is located on 10 km thick crust with low velocity (<6.5 km/s). In contrast, the crust southeast of the adjacent Murray Ridge is only 4 km thick and characterized by high velocities (up to 7.2 km/s).

SE48 Gas hydrates in nature: results from geophysical and geochemical studies

Convener: Pecher, I.A.
Co-Convener: Kukowski, N.

UNEXPLAINED SEISMIC AND VOLCANIC GAPS IN THE N. ANDES: EFFECTS OF THE SUBDUCTION OF CARNEGIE RIDGE?

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Along the NW margin of S. America, the Carnegie Ridge (300 km wide, 2 km high) enters into subduction at the Colombia trench. Four great quakes (M_w > 7.8) occured here this century, incl. the great 1906 quake ($M_w = 8.8$) with an estimated rupture zone of 500 km. The pattern of seismicity as shown by ca. 2600 events ($M_b > 4.0$) recorded since 1900 reveals a significant seismic gap at depth in the continuation of the Carnegie Ridge (2°N - 1°S). Active arc volcanicism in this zone is more diffuse than to the N or S, but remains widespread. Only S of 2°S is a volcanic gap present. Recent plate motion models (DeMets et al. 1990) and GPS studies (Kellogg & Vega, 1995) indicate E-W convergence of 5 - 7 cm/a, with a slight NW-SE component. Thus the ridge sweeps gradually S with respect to stable S. America and cannot explain the volcanic gap to the S. The typical pattern of shallow subduction and associated volcanic gap commonly associated with the subduction of an aseismic ridge is absent here. Seismological cross sections show that subduction is steep immediately N and S of the ridge and arc volcanism persists. Strong coastal uplift (300 - 500 m) facing the subducting ridge and subsidence to the N suggest a continuation of the ridge beneath the margin. This conflicts with tectonic models for formation of the E. Panama basin oceanic crust suggesting that the Carnegie Ridge entered the trench ca. 1 Ma, thus extending at most 70 km from the trench.

CRUSTAL STRUCTURE OF THE MURRAY RIDGE AND DALRYMPLE TROUGH: LITHOSPHERE UNDER OBLIQUE EXTENSION

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The Dalrymple Trough is a linear trough 160 km long and about 1.5 km deeper than the adjacent Oman Abyssal Plain, which marks the boundary between the Arabian and Indian plates in the Northern Arabian Sea. To its southeast lies the Murray Ridge, a broad bathymetric high. Earthquake focal mechanisms and seismic reflection profiles show that the trough has been undergoing recent oblique extension. We present initial results from a bathymetric and wide-angle seismic study carried out in 1997. The trough is bounded to the southeast by a steep and continuous 2 km fault scarp, and to the northwest by a series of en echelon scarps each ~ 10 km long. To the northwest, the seismic velocity structure is typically oceanic, with an unusually large velocity discontinuity between Layers 2 and 3 and a crustal thickness of ~ 6 km. Beneath the Dalrymple Trough, however, the crustal thickness increases to ~ 10 km and velocities are lower than for typical oceanic crust. These results could be interpreted to indicate either that oceanic crust in the trough has been extensively tectonised and altered, or that the trough and the adjacent Murray Ridge represent a fragment of continental India.

THE OCCURRENCE AND ORIGIN OF A BOTTOM-SIMULATING REFLECTOR IN THE NATAL VALLEY, OFFSHORE SOUTHEASTERN AFRICA

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A bottom-simulating reflector (BSR) is recognised over a wide area of the continental rise and outer rise lobe within the submarine Natal Valley, an area of relatively high Neogene sedimentation rate and neotectonic deformation. Similar BSR occurrences are seen across the neighbouring Agulhas-Falkland Fracture Zone sheared margin of South Africa. BSR appearances are not at all random, but have well defined geographical limits. A strong BSR is largely restricted to the northern, crustally older (Early Cretaceous) corner of the abyssal Natal Valley, and to parts of the continental rise. The BSR generally becomes weaker in appearance away from these thick continental rise deposits, and disappears in an oceanward direction around a deep (>4000 m) zone of "broken sea floor", near the transition to the abyssal plain of the Transkei basin. The gas hydrate may generage from Cretaceous anoxic deposits related to the enclosed basin conditions that existed during the early stages of separation between the Falkland Plateau, Mozambique Ridge and Agulhas Plateau. Because the adjacent continental margin is so steep and narrow, a significant sea level fall could trigger a major instability in the continental slope deposits.

LABORATORY INVESTIGATION OF GAS HYDRATE GENESIS IN SEDIMENTS: MODES OF OCCURRENCE, VOLUMES AND GROWTH PATTERNS

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The growth of methane clathrate hydrate in marine sediments is being investigated using GHASTLI, a custom-built test system. P-T conditions used are within the range of natural occurrence, and silt- or sand-sized sediment are the host media. Analyses focus on 1) electrical resistivity images, 2) acoustic velocities, 3) thermal anomalies, 4) pore pressures, 5) gas mass balances, and 6) direct inspections of the final hydrate-bearing sediment. The research examines potential gross relationships between pore properties and mode of occurrence (habit) of the hydrate. Experiments in sands have resulted in 15% to 80% of pore space being filled with gas hydrate, which loosely to fully cements the grains. Preliminary experiments on silt have resulted in the formation of a few isolated hydrate grains. Additionally, these initial tests show the feasibility of establishing a relationship between acoustic properties and hydrate quantity.

GENERAL CHARACTERISTICS OF THE BLACK SEA MUD VOLCANOES AND GAS HYDRATES "SHIELD" IN THE EASTERN MEDITERRANEAN SEA

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Many of the Black Sea and Mediterranean Sea mud volcanoes were discovered and studied using the seismic reflection profiles by TREDMAR/UNESCO Cruises. The main of the this work is to analyse these data in order to reveal some general features inherent to the mud volcanoes, and to point at the same time, their differences, due to regional peculiarities. The known mud volcanoes seem to be randomly distributed and do not show alignment. Their forms resemble creaters with rims consisting of extruded mud and mud brecia and with large mud flows at their slopes. On the seismic sections the mud volcanoes show dom-like positive features, acoustically transparent zones, the local subsurface presence of gas in the form of bright spots in Black Sea. On the Mediterranean Ridge, several mud volcanoes and dome-like structures have been discovered from the seismic reflection profiles. These features show an up-doming structure, transparent zone below the dome, reflectors downbended nearby the mud volcanoes, gas hydrate "shield" in the dome like structures. The Bottom Simulating Reflections (BSR) indicate most frequently the bottom of a gas hydrate saturated layer.

BIOLOGICAL ACTIVITY, RELATIVE SEDIMENT PERMEABILITY, AND SEISMIC EVENTS

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This paper reports experiments we conducted to demonstrate possible connections between microbiological methane production, relative-permeability effects, and development of bottom simulating reflectors (BSRs). A concept developed by Benzing (1994) and numerically modeled by Benzing and Shook (1996) shows how pressure seals within homogeneous shales may create a two-phase system at a particular isotherm. Isotherms and the resulting pressure seals are observed to cross lithologic boundaries, so seismic effects will also cross lithologic boundaries. Our recent work has shown methanogenic organisms survive and produce methane at pressures and temperatures suitable for stable methane hydrate. Work was conducted to determine if microorganisms could be directly involved in methane exsolution at sedimentary isotherms. Methanogens were cultured at temperature and elevated pressure and excess methane saturation to simulate conditions in or below hydrate or free-gas zones. After suitable incubation times, cultures were evaluated for growth and methanogenic activity by microscopic and molecular techniques. Methane production under these conditions implies super-saturation, which would be accompanied by exsolution and gas entrapment under certain environmental conditions.

EVIDENCE OF PRESENCE OF GAS HYDRATES IN LAKE BAIKAL BOTTOM SEDIMENTS, BASED ON *IN SITU* MEASUREMENTS OF THERMAL CONDUCTIVITY

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In course of geothermic studies of Lake Baikal a few hundred *in situ* measurements of bottom sediment thermal conductivity (**k**) have been performed by a needle-probe penetrated down to 3 m into sediments. The probe, electrically heated from inside, is a linear source of heat and heats up sediments around it. The measurements revealed dramatic irregularities in temperature rise of the probe and hence in heating of surrounding the probe bottom sediments in some local regions of the lake. In some of these abnormal cases, **k** values, calculated for different time intervals from the beginning of heating, varied from 0.5 to 1.5 W/m°K. Examination of these cases showed the irregularities occure only if heat input into the probe and hence its temperature achieve some certain values. It can be hypothesised that the irregularities can appear if some part of sediment pore space is filled with gas hydrate which is dissociated by heating during measurements of the **k**. The heat of fusion of methane hydrate is 500 J/g that is 1.5 times as great as that of ice. Therefore, at the first stage of heating cycle, a lot of heat is taken up not for increasing the temperature ot bottom sediments but for fusion of gas hydrate disseminated throughout porous sediments. The released free gas reduces **k** at the following second stage of heating. The presence of gas hydrate even in 1% of sediment pore space can yield two- or three-fold variation of **k**.

HEAT FLOW VARIATIONS FROM BOTTOM SIMULATING REFLECTORS ON THE CASCADIA MARGIN

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In September 1996, a collaborative experiment between the University of Victoria and the Geological Survey of Canada focussed on the marine gas hydrate layer found on the continental slope off Vancouver Island.Multichannel seismic data were collected along several grids at a nominal linespacing of 400 m. Data were recorded on a 24-channel streamer with a maximum source-receiveroffset of only 290 m. Processing was complicated by an offset-dependent ghostreflection, caused mainly by variation in depth of the receiver array. Velocity analyses were performed before stacking, but velocity estimates were not reliable due to shortsource-receiver offsets. Estimates of heat flow values were made from the depth ofthe bottom simulating reflector (BSR), which is the base of the hydrate stabilityfield. The average heat flow value was around 70 mW/m2, consistent with measurements from seafloor temperature probes and Ocean Drilling Program results on the Cascadiamargin. The regional trend of the heat flow values shows a landward decrease which reflectsthe processes due to sedimentation at the margin, tectonic thickening at the outer part of the accretionary prism and subduction of the Juan de Fuca plate. Very high heatflow values were observed at the flanks of topographic highs, suggesting fluidmigration along thrust channels. Above some topographic highs, relatively low heat flow values were observed, possibly due to the underthrusting of cooler material.

ANALYSIS OF HIGH-RESOLUTION DEEP-TOW MULTICHANNEL DATA FROM VANCOUVER ISLAND HYDRATE SITES

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High-resolution multichannel data were collected during April 1997 in the vicinity of ODP site 889B using the Deep-Tow Acoustics/Geophysics System (DTAGS). This site lies in a well-studied region of gas hydrates off the West coast of Vancouver Island. The DTAGS system uses a Helmholtz resonator to generate a 205 dB frequency sweep between 250 Hz and 650 Hz. Data were collected on a 49-channel array, with 622 m maximum offset. The large bandwidth and higher-than-usual frequencies allow much better resolution of fine structure in the upper sediment than can be obtained from standard multichannel data. However, data processing requires much more accurate positioning of the source and receiver elements. The large tow depths ($\approx$800-1200 m) made accurate positioning of the array elements difficult. Significant changes in the depth of the system occurred during most of the experiment, and the array was not sufficiently horizontal that differences in depths between array elements could be neglected. Consequently a method of estimating element depths using sea-surface reflection times was developed. Time corrections based on these measurements were applied to the data to account for the non-constant depths. Standard velocity analysis was then applied to the depth-corrected data. Results of these analyses are compared with those obtained from standard single and multichannel data collected at the same sites.

SQUEEZING THE SPONGE: GAS AND FLUID ALONG THE HIKURANGI MARGIN, NORTH ISLAND, NEW ZEALAND

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Along the East Coast of the North Island of New Zealand the accretionary prism is being rapidly deformed by convergent motion of the Pacific Plate as it subducts beneath the crust of the Australian plate. Pore-pressure trends in oil wells on the East Coast indicate the region is strongly over-pressured and in some wells the fluid pressure is close to lithostatic at 1 km depth. Along the emergent parts of the Hikurangi accretionary wedge are numerous springs, gas and oil seeps, and explosive mud volcanoes, commonly associated with buckle folds and diapiric structures. Fluids samples from 15 sites show high salinities and are enriched in both deuterium and oxygen-18, supporting a seawater origin for the discharging waters. Gas chromatography indicates that methane is the dominant gas type from seeps and hydrogen isotopic compositions suggest that the gases probably have a thermogenic origin. Seeps and fluids venting offshore are marked by distinctive chemosynthetic faunas and carbonate chimneys and lie just landward of a bottom simulating reflectors (BSR's) observed on seismic reflection profiles. The mapped distribution of BSR's is restricted to water depths between 1 and 3 km and are especially prominent along actively growing anticlinal ridges that are often cored by thrust faults. Geological, geochemical, and seismic evidence suggest that coupling between fluid and deformation regimes occurs where fluid migration takes places by episodic release along high permeability zones rather than diffuse flow.

SOLUTE TRANSPORT MECHANISMS IN BLAKE-RIDGE SUBMARINE GAS-HYDRATE ZONE: HALOGENS, CHLORINE, OXYGENE AND HYDROGENE ISOTOPES (ODP LEG 164)

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Coupled chlorinity and oxygen isotopic anomalies are necessary and sufficient conditions for the occurrence of submarine gas-hydrates, based on the characteristics of their pore waters alone. Salt exclusion and fractionation of the heavy isotopes into the solid hydrate phase cause a chlorinity maximum and O- and H-isotope minimum at the top of the hydrate zone. At Blake Ridge, the roof of the hydrate zone may be as shallow as 24 mbsf, where hydrate effects are superposed by glacial-interglaical seawater variations affecting the chlorinity and isotopic composition of the pore fluids. The chlorinity minimum and O-isotopic maximum resulting from hydrate melting at the base of the hydrate zone cause strong vertical concentration gradients inducing diffusion of the species affected. Hydrate melting as an artefact of the sampling process, however, has the same effects of pore-water freshening and heavy-isotope enrichment. Whereas in the past, the effects of the different processes could not be separated, in-situ water samples combined with chlorine isotopes of the samples squeezed on board seem to provide strong evidence for downward chloride diffusion. Bromine/iodine ratios provide constraints on upward advection rates. Modelling of the Leg 164 results will allow us to quantitatively assess the effects of the processes involved in solute transport in the classical Blake Ridge hydrate field.

THREE-DIMENSIONAL SEISMIC TOMOGRAPHIC STUDIES OF THE METHANE HYDRATE STABILITY ZONE IN THE CASCADIA MARGIN

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We present results from a three-dimensional seismic tomography experiment focused on the gas hydrate bearing zone around Ocean Drilling Program Site 889 on the Vancouver Island margin. The experiment involved two deployments of five ocean bottom hydrophones (OBHs) and shooting a single 120 cu. in. airgun at ~35 m intervals along 25 15-25 km long profiles at a variety of azimuths. OBH record sections show reflections from the bottom simulating reflector (BSR) and a variety of horizons above the BSR, and energy turning within and beneath the hydrate stability zone. Our tomographic model is also constrained by a vertical seismic profile at Site 889 and a tight grid of seismic reflection profiles around this site. The model is parameterised as a series of layers within which velocities vary in three dimensions, bounded by reflecting surfaces of arbitrary three-dimensional shape. Our method involves gradually decreasing model smoothness until travel-time picks are matched to within their uncertainties. Preliminary results show that the inversion is stable, that velocities reach 1.83-1.95 km/s immediately above the BSR, indicating increased hydrate content in this zone, and that there may be a correlation between hydrate concentration and BSR strength. Our results will be interpreted in terms of three-dimensional hydrate distribution around Site 889.

ELASTIC PROPERTIES OF HYDRATE-BEARING SEDIMENTS FROM EFFECTIVE MEDIUM THEORIES

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A variety of sophisticated methods have been developed to infer the detailed seismic velocity structure of hydrate-bearing sediments from multichannel and wide-angle seismic data. However, estimation of hydrate content from this velocity information still commonly relies on semi-empirical relations with little theoretical basis. We present a model based on effective medium theories to relate the seismic properties of hydrate-bearing clay-rich sediment to its porosity and mineralogy, the orientation distribution of clay platelets, and the quantity and topology of hydrates in the pore space. The model is transversely isotropic and based on a combination of the self-consistent approximation, the differential effective medium theory, and the method of smoothing for crystalline aggregates. A similar combination of effective medium theories has previously been applied successfully to shale. We consider two endmember cases: hydrate as a connected phase lining the pores, and disconnected hydrate nodules. The latter model appears to be more appropriate for naturally occuring hydrates in fine-grained sediments. We apply our method to sediments cored at Ocean Drilling Program Site 995 to make estimates of their hydrate content.

SUBMARINE GAS HYDRATES: MECHANISM OF FORMATION AND ACCUMULATION

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Submarine gas hydrates were observed near sea-bottom in the gas or gas-containing fluid discharge areas and in the sections of sediment cover in the areas which have not connection with fluid discharge areas. The theoretical and experimental data suggest that submarine gas hydrate formation results mainly from water-dissolved gas. Gas hydrate accumulation is attended by water segregation and formation of specific structures caused by hydrates in sediments. The detection of water content of gas hydrate-containing sediments as well as published experimental data testify that there is water migration to sites of gas hydrate accumulation from surrounding space. The most dramatic evidences of water migration and segregation during gas hydrate accumulation have been discovered at the studied gas hydrate occurrences: gas discharge areas in the Okhotsk Sea, mud volcanoes in the Caspian and Norwegian Seas, gas hydrate-bearing sediments on the Blake Outer Ridge. The direct relationship of water content with hydrate content and opposite relation with pore water chlorinity have been revealed. The considered data allow to make the conclusion that water migration and segregation are an integral component of gas hydrate accumulation in the submarine environments.

Global Change, Gas Hydrate, and Mass Wasting of the Continental Slope

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Numerous continental slopes (for example, offshore Alaska, continental U.S., Norway, and Africa) are notable by the coincident association of landslide deposits and sediment containing gas hydrate, a solid inclusion compound of methane and water that forms under conditions of high pressure and low temperature. Pleistocene fluctuations in global climate, manifest in periodic sea-level regressions, likely triggered landslides on the continental slopes where gas hydrate is present in seafloor sediment. Eustatic sea level fall causes reduced pressures acting on seafloor sediment. In oceanic areas underlain by sediment containing gas hydrate, this reduction of confining pressure initiates dissassociation along the base of the gas hydrate zone. In turn, large volumes of gas are released into the sediment which likely leads to excess pore-fluid pressures and reduced slope stability.

A quantitative modelling approach was taken to predict excess pore fluid pressures at the base of a dissassociating gas hydrate zone and the stability of the overlying sediment for a variety of sediment types. Our studies indicate that during eustatic sea level fall, fluid diffusion processes drive the gas hydrate dissassociation process in fine-grained marine sediment. Slope failure appears likely for this sediment type on moderate slopes unless methane can be adequately vented away from the base of the gas hydrate zone and into the water column. When landsliding occurs, sediment is deformed and fractured, allowing methane to be released into the water column. As a consequence, we believe that periods of peak glaciation, when sea levels are at their lowest, are associated with the large- scale mass wasting of gas hydrate-laden continental marginns resulting in the release worldwide of large volumes of the greenhouse gas methane, and thus influencing global climate changes.

COMPARISON OF GAS HYDRATE COMPOSITION FROM THE MIDDLE AMERICA TRENCH AND BLAKE RIDGE

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Gas hydrate samples were recovered from the Middle America Trench, an active margin offshore Costa Rica during ODP Leg 170 and from of the Blake Ridge on the passive Atlantic margin of the eastern U.S. during ODP Leg 164. Offshore Costa Rica (CR), gas hydrate from Site 1041 was recovered 100 to 280 meters below the sea floor (mbsf) within a sedimentary apron of 500-600 m thickness that overlies an accretionary prism. Gas hydrate occurs primarily as very layers in the upper section and as pore filling cement within volcanic ash layers in the deeper section. On the sedimentary drift deposits of the Blake Ridge (BR), gas hydrate samples were recovered from three Sites (994, 996, and 997). At Site 996, an area of active gas venting, vein-like gas hydrate was recovered intermittently from less than 1 to 62 mbsf. Gas hydrate at Sites 994 and 997 occurs from about 180 to 450 mbsf and is dispersed in zones of sediment 5 to 30 m thick having a maximum 15% bulk volume gas hydrate with occasional massive gas hydrate occurring in fault planes. In our shore-based laboratory, selected gas hydrate samples, which had been stored in liquid nitrogen after collection, were placed in a sealed chamber and allowed to dissociate. Gas hydrate gas to water ratios and evolved gas composition were measured after dissociation. The most significant comparisons follow: Evolved gas to water ratios of 80 to 110 (CR), and 20 to 154 (BR) were measured as compared to the theoretical maximum of 216; Gas hydrate methane concentration and carbon isotopic composition were determined: CR: 99.4 to 99.8%, -62.4 to -67.3‰; BR: 98.4 to 99.9%, -62.5 to -70.7‰. In both cases carbon isotopic compositions become heavier with depth yet still retain a microbial signature. Ethane concentrations ranged from 190 to 1200 ppm (CR), and 86 to 1000 (BR). Carbon dioxide was present in most samples from each margin. Thus little differences could be observed between the results of the gas hydrates from the active and passive margin. It is likely that gas hydrate composition and gas yield depend little on the tectonic setting but more on the sources of methane.

CALCULATING THE INCIPIENT OF HYDRATE FORMATION TEMPERATURES IN SOLUTIONS CONTAINING ALCOHOLS AND ELECTROLYTES

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The freezing point depression equation is also valid, to some extend, for hydrate depression temperature. This equation in a truncated form can be expressed by:

$$\ln a_w = \frac{\Delta H}{nR}\left(\frac{1}{T_o} - \frac{1}{T}\right) \tag{1}$$

Where a_w is water activity, ΔH is heat of hydrate formation, R is universal gas constant, n is hydrate number, T is hydrate formation temperature of solution, and T_o is hydrate formation temperature of pure water. In the present study, T_o is calculated by one of statistical models based on van der Waals's model. In a_w and ΔH/nR will be calculated by suitable combining rules, once In a_w and ΔH/nR in the presence of electrolytes and also in the presence of alcohols have been calculated. Following this methodology, the incipient of hydrate formation in the mixtures of both electrolytes and alcohols was calculated. The average of absolute deviation for the prediction of a typical natural gas and CO_2 hydrate in the mixtures containing electrolytes, such as KCl, NaCl and $CaCl_2$ and alcohols such as methanol, ethylene glycol and glycerol was 0.96 K for 71 data points.

MARINE GAS HYDRATES AND METHANE RICH COLD SEEPS IN NANKAI TROUGH, OFF CENTRAL JAPAN

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Two 250 m-deep test wells were drilled at the water depth of ~950 m in Nankai trough in which well defined BSRs occur at ~300 mbsf. The sediments are dominated by slightly calcareous, dark greenish gray clay/silt whereas the lower part is more sandy with frequent intercalation of turbidites. Chloride concentrations of the interstitial waters generally decrease from 560 mM at sea-floor to 510~530 mM for the interval of 100-250 mbsf with irregular zig-zag pattern and occasional strong negative spikes (380~450 mM). The pore saturation of gas hydrates is estimated to be 3 ~ 30%, mostly between 3 and 5% for the entire depth interval.

Cold seep sites with well developed chemosynthetic community had been observed in the floor of Ryu-yo Canyon (~1100 m water depth) only ~2 km southeast of the drill sites (Tsunogai et al., 1998). Pore waters suqeezed from the seep site sediments were characterized by anomalously low chloride (~520 mM) and high methane (340 mM) concentrations. Cold seeps in accretionary prisms have often been related with accretion processes, but the Ryu-yo Canyon seepage are more likely related with decomposition of gas hydrates.

BSRs OFFSHORE COSTA RICA

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The Costa Rica convergent margin between the Nicoya and Osa Peninsulas is divided into a southeastern part having a disturbed slope and a northwestern part having a relatively smooth seafloor morphology. The disturbed topography is caused by subduction of many seamounts, which has produced scars on the slope. Bottom simulating reflectors (BSRs), which are probably gas horizons beneath hydrate zones, are wide-spread where the seafloor is less disturbed by seamount subduction. The subduction of seamounts causes uplift of the slope. In these areas, the reduction of pressure leads to dissociation of hydrate, the formation of free gas, and perhaps overpressuring at the base of hydrate stability. BSRs are absent in regions in which sediment stratification has been destroyed by slope failure, suggesting that BSRs either do not form after slumping or take a very long time to do so. High fluid expulsion rates are expected at this margin because most of the sediment is being subducted. A maximum in heat flux computed from the depth of BSRs is observed at the lower slope, where expulsion of warm fluids is expected to be highest. Heat flux decreases northwestward along the margin. Heat flux values close to the trench at the northwestern edge of the study area, however, are significantly higher than those measured during ODP Leg 170 only about 30 km further to the northwest. This observation has yet to be explained.

A SINGLE-CHANNEL SEISMIC REFLECTION METHOD FOR QUANTIFYING LATERAL VARIATIONS IN BSR REFLECTIVITY

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Results of seismic inversion techniques and logs of deep-sea bore holes indicate that bottom simulating reflectors (BSRs) associated with high-amplitude reflections are underlain by a thin layer of free gas. Reflections from BSRs often are of relatively low amplitude, however, and commonly display significant lateral variability. The structure that generates this is not well understood and remains a topic of research.

The use of waveform inversion to study the structure of BSRs requires multi-channel data sets that include large source-receiver offset distances. Since such data are not readily available, it is attractive to consider other methods.

A method that is applicable to single-channel data is discussed here. It requires that the source-receiver offset distance be small compared to the water depth and that reflector dips be gentle; prerequisites that usually are satisfied in the context of BSRs. It also requires that the data be recorded digitally at a rapid sampling rate and that the recording extend until the onset of the second water-layer multiple; prerequisites that are satisfied less often.

The method is explained and illustrated with the help of synthetic data. Its application to actual seismograms is demonstrated and results compared to full waveform inversions. Aspects of its use are discussed and conclusions are drawn.

STABLE ISOTOPE COMPOSITION AND MINERALOGY OF THE DIAGENETIC CARBONATES ASSOCIATED WITH THE GAS HYDRATES IN THE SEDIMENTS OF THE BLAKE RIDGE (ODP LEG 164)

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During ODP Leg 164 (November-December 1995), gas hydrates were recovered in the large reservoir of the Blake Ridge where the top of the gaz hydrate zone lies at about 200 metres below the sea floor (mbsf) and the bottom simulating reflector (BSR) is located at about 450 mbsf. There is no sedimentological discontinuity crossing the BSR. The authigenic carbonates (dolomite, siderite) are always present in small amounts (a few weight %) in the sediments; they are also concentrated in mm to cm-sized nodules and layers composed of dolomite above the top of the gas hydrate reservoir, and of siderite below the BSR. The distribution with depth of the $\partial^{18}O$ values of dolomite and siderite shows a sharp decrease from high values (max 7.3‰) near 50 mbsf to very low values (min -4.7‰) at 110 mbsf, and finally increases to values within the range of 3.4 to 6.6‰. The $\partial^{13}C$ distribution is marked by the rapid decrease from low values (-11.4‰) near 50 mbsf to positive values at 110 mbsf which remain in the range of 1.7 to 5.4‰ down to 700 mbsf. Thus, diagenetic carbonates were precipitated in pore waters, in which $\partial^{18}O$ and $\partial^{13}C$ values were highly modified by strong fractionation effects, both in the water and in the CO_2-CH_4 systems, associated with the formation of gas hydrates .

DOUBLE BSRS AS INDICATORS FOR CHANGES IN THE HYDRATE STABILITY FIELD ON THE NORWEGIAN CONTINENTAL MARGIN

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The presence of gas hydrates and free gas in oceanic sediments along the northeastern European margin is documented in seismic data. On the northern rim of the Storegga slide, which is located on the western continental margin of Norway south of the V÷ring Plateau, the lower boundary of the hydrate stability zone (HSZ) is determined in high resolution reflection seismic data by a strong bottom simulating reflection (BSR). Velocity informations from HF-OBH data show anomalously high velocities above the BSR indicating the existance of gas hydrates, whereas extreme low velocities below the BSR are interpreted as gas bearing sediments. The observation of low velocity layers within the HSZ as well as the obeservation of a double-BSR in seismic sections leads to the question, if the position of the BSR necessarily coincides with the actual lower boundary of the HSZ. Modelling of changes of the HSZ as a function of the temperature and pressure show a distinct decrease of the HSZ at the Norwegian margin from the last glacial maximum to the present time. This highly dynamic HSZ behaviour may be essential for the appearance of unusual seismic features in areas of gas hydrat formation.

GEOPHYSICAL EVIDENCE FOR DENSE MASSES OF METHANE HYDRATE IN THE DEEP BERING SEA BASIN

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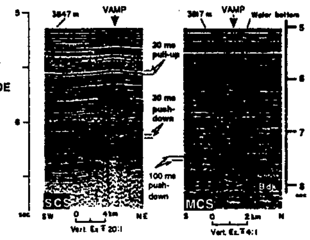
Seismic reflection records and velocity anomalies indicated that the Bering Sea Basin (3,500-4,000 m) is shallowly (0-450 m) underlain by localized, massive accumulations (> ~ 30 % of pore space) of methane hydrate. Dense concentrations are detected as prominent velocity and reflection-amplitude anomalies known as VAMPs, which are interpreted to be lateral velocity distortion in horizontal beds caused by the superposition of a velocity pull-up directly above a velocity push-down. The pull-up is interpreted to be a massive deposit of methane hydrate accumulated in turbidite beds overlying a column of thermogenic gas ascending to the sea floor through diagenetically contracted siliceous deposits of Miocene age. At a large VAMP (pull-up = 30 ms, push-down = 80 ms), the minimum volume of methane involved is about 0.8 X 10^9 m^3 (0.3 TCF), which is equivalent to a large gas field.

VAMP STRUCTURES
(Velocity-Amplitude Anomalies)
ARE EXHIBITED ON REFLECTION RECORDS
AS ARCHED HORIZONS (velocity pull-up)
ABOVE A PHASE-INVERTED, HIGH-AMPLITUDE
REFLECTION (BSR)
OVERLYING DOWNFLEXED HORIZONS
(velocity push-down)



IS BLANKING EFFECT ASSOCIATED WITH HIGH VELOCITY HYDRATE BEARING SEDIMENTS ABOVE BSR?

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Unreflective zones above bottom simulating reflectors (BSR) are sometimes interpreted to be due to a decrease in impedance contrasts that might result from the presence hydrates in the pores space. However, VSP results from ODP Leg 164 on the Blake Ridge, the classic example of such "blanking", suggest that this effect is rather due to the highly uniform lithology in the region. A multichannel seismic dataset from the continental margin of Japan suggests that blanking there might be associated with the presence of a strong BSR.
We use a combination of a Genetic Algorithm (GA) based migration velocity method (Geneva) and a seismic waveform inversion method to obtain a *P*-wave velocity distribution above the BSR. The 1-D full waveform inversion resolves the fine scale velocity structure by minimising the misfit between synthetic and observed seismic data sample-by-sample. Geneva is a 2-D prestack depth imaging procedure using GA to find the optimum velocity model. Regions of smooth variation are identified and sparsely parameterised by nodes describing long and short wavelength velocity variations. The best model is achieved by maximising the flatness of common image gathers in the vicinity of reflectors. The velocity from the waveform inversion at various locations indicates different velocity structures above the BSR. Preliminary results from Geneva seem to suggest an association of high velocities with zones of low reflectivity.

GAS HYDRATES IN THE SEABED SEDIMENTS ON THE NORTH-EASTERN PART OF THE BLACK SEA

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A rich collection of gas hydrates was sampled during the 6th "Training-Through-Research" expedition, which was carried out in 1996 in the Black Sea. The study region is a newly discovered area of the extensive fluid flux and gas venting on the seafloor. This area is known by the Oligocene-Low Miocene mud deapiric structures. Some of the diapirs are crowned by mud volcanoes. Abundant gas hydrates were found in mud breccia at the 5 sites, at water depth ranging from 1850 to 2100 m. The gas from the gas hydrates appeared to be mostly methane (97.7%-99.9%). However, some gas hydrate samples are noted for presence of small admixture of heavy hydrocarbons up to i-hexanes. The pore water from the sampling site BS288G containing gas hydrates is twice desalinises as normal Black Sea water. In this core the Cl^- constitutes 343.66 mgeq/l in the uppermost part and decreases up to 184.23 mgeq/l in the gas hydrated layer. In addition, several layers of this core are characterised by large fall of the Ca^{2+} and Mg^{2+}concentrations. Those falls correlates with the appearance of the outhigenic carbonate minerals within this core.

Broad-band seismic data acquisitions for fine scale imaging and velocity determination associated with BSR

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In order to finely image BSR (bottom simulating reflectors) and their velocity structures, a couple of experimental seismic surveys (MCS, DTAGS, OBS) were conducted in the continental margin facing the Eastern Nankai Trough. Based on these survey data, several seismic features associated with the BSR are interpreted and evaluated quantitatively.

Seismic blanking effect characterized by the lack of reflections above BSR is not common in active margins. But in the current surveys, blanking zone is identified in some restricted area over broad frequency bands. Interesting character of this blanking is the amplitude increase of BSR strongly at the farther offset distance due to turning ray effects. By the tomographic coherency inversion technique the interval velocity structure is estimated.
Transverse wave velocities are estimated by means of traveltime inversion of the observed transverse waves converted at BSR and waveform fitting with model syntheses for multichannel OBS data.

Seismic sections clearly shows steeply dipped normal faults reaching the seafloor and/or the base of the deformed unconsolidated sediment, and strong amplitude sediment layers intersected with BSRs which may be considered conduit of liquid migration. Lateral BSR amplitude weakening is interpreted as the subsidence of the layers.

REFLECTED AND REFRACTED SEISMIC IMAGES OF THE BSR IN THE SOUTH SHETLAND MARGIN (ANTARCTIC PENINSULA)

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A Bottom Simulating Reflector (BSR) present on the South Shetland Margin has been extensively surveyed during February 1997 by the *R/V OGS-Explora*, with the main scope to map its extent and to reveal its acoustic characteristic. About 750 km of high resolution multichannel and single channel seismic reflection profiles have been acquired, and a three-component Ocean Bottom Seismometer (OBS) was deployed. So, we increase the information on the physical properties of gas hydrate- and free gas-bearing sediments. We found that the BSR is present along the margin in water depths ranging from 1400 to 2300 m. It is clearly superimposed on the sedimentary reflector configuration of the margin, and this is particularly evident in areas where it crosses folded and deformed sequences. Preliminary data analysis has shown that the BSR is locally offset by structural discontinuities (faults), and we propose the hypothesis that the faults act as conduits for migration of natural gas towards the surface, controlling the gas hydrate and the free gas distribution. We estimated from theoretical models and from compressional and shear velocities attributes the amounts of free gas and gas hydrate in this margin where the BSR occurs, with percentages for both components smaller than 15% in the pore space.

AN INTEGRATED STUDY OF SEISMIC AND HYDROTHERMAL CHARACTERISTICS ON THE CLATHRATE BEARING SEDIMENTS OF THE MAKRAN ACCRETIONARY WEDGE OFF PAKISTAN

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During cruise SO124 single-channel seismic and geothermal measurements were carried out across the southern part of the Makran accretionary complex south of Pakistan. The accretionary complex is well known for its thick pile of sediments. The detailed mapping of the BSR in combination with closely spaced heatflow measurements will help to answer the question, if heat is transferred in a diffuse manner through the sediments due to expulsion of pore fluids. Crucial for the calculation of the temperature at the depth of the BSR is a detailed velocity-depth-profile, which is derived from wide-angle refraction surveys and near vertical incident reflexions recorded with high-frequency ocean-bottom hydrophones. The reflexion data reveal the very continues and sharp appearance of the BSR along strike and across.

NEOTECTONIS AND THE ORIGINS OF BSRs ALONG THE PERU MARGIN

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The distribution of BSRs across the Peru margin appears related to tectonic uplift and carbon content of sediment. Where the active acretion of deep ocean pelagic sediment containing less than 1% carbon is seismically imaged, no BSR is formed. Also no BSR forms in carbon-rich (4% - 8%) sediment of the subsiding Lima Basin. Conversely, BSRs are abundant in carbon-rich sediment affected by tectonic uplift and/ or rapid sedimentation. These BSRs are formed as soon as small amounts of free gas contact the base of the hydrated sediment. The free gas is probably released from gas hydrates during uplift or sedimentation by dissociation as the hydrate phase boundary shifts upward. However, during the subsidence of Lima Basin, free gas may be hydrated as subsidence causes the phase boundary to shift downward. although gas hydrate is affected by several factors, vertical motion and carbon content of the sediment seem dominant along the Peru convergent margin.

DEEP TOWED MULTICHANNEL SURVEY TO STUDY THE GAS HYDRATES OFFSHORE VANCOUVER ISLAND

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A deep towed high-resolution seismic survey, offshore Vancouver Island, was carried out in May 1997 in collaboration with the US Naval Research Laboratory. The survey was carried out using a Deep Towed Acoustic/Geophysics system (DTAGS), which consists of 2 subarrays of 24 hydrophone groups each (group spacing: 2.1m for the first array and 21m for the second). It uses a Helmholtz resonator source, generating a linear sweep from 250-650Hz over 0.25s with signal strength sufficient to sample the upper 500m of the sediments. The system was towed at depths of about 1km in water of depth ~1.3km. Difficulties in processing arise due to shot-to-shot variations in the depth of the source and the hydrophone groups. However, the dataset promises excellent temporal and spatial resolution. The preliminary near-channel stack section has shown several sub-seafloor reflectors with fine spatial details. More interesting results such as small-scale structures within hydrated layer, particularly around BSR, and the precise velocities, required for hydrate/gas saturation estimation above/below BSR, are expected from the processing of the far offset multichannel array. In this paper we present a generalized approach of processing and a comparison of DTAG sections and velocities with those from single channel and multichannel data previously acquired using airgun sources.

A LABORATORY SYSTEM FOR CREATING AND TESTING GAS HYDRATES WITHIN SEDIMENT

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A unique laboratory instrument (GHASTLI: Gas Hydrate And Sediment Test Laboratory Instrument) has been used to form gas hydrates within different types of materials and measure their mass physical properties. In addition, we have performed tests on marine sediment from the Blake Ridge region, where naturally occurring gas hydrates were recovered during ODP Leg 164, to determine consolidation stress history and engineering properties (e.g., shear strength, which can be used for slope stability analyses). The system simulates sub-seabed overburden conditions by imposing a confining pressure (≤2500-m water depth) externally to a test specimen while maintaining a constant internal pore pressure. Methane and sea water can be introduced using a computer-controlled flow rate or differential pressure by syringe pumps or by a separate hydraulic pressure intensifier system. Four ports at the ends of the cylindrical specimen enable distribution and collection of fluids or gases and their measurement using a back pressure sub-system. A unidirectional temperature gradient is controlled with a heat exchanger located at the top of the sample. Acoustic velocity and electric resistance have been measured before and during hydrate formation and after dissociation.

TWO-PHASE EQUILIBRIA BETWEEN HYDRATE AND SEAWATER

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The solubility of methane gas in seawater is calculated over a range of pressure and temperature. The gas in seawater coexists with either free gas at high temperature or solid hydrate at low temperature and high pressure. We show that the solubility of methane decreases sharply with temperature when the hydrate phase is present. In effect, gas is transfered from solution to hydrate as the hydrate phase becomes more stable. Such an abrupt decrease in solubility permits hydrate to crystallize directly from the aqueous solution, without the need of any free (bulk) gas. Quantitative estimates of the phase equilibrium are also important for the dissociation of hydrate, which may represent a positive feedback on global warming or a negative feedback to advancing glaciation. We model the decomposition of hydrate caused by plausible changes in temperature and pressure on the basis of the governing equations for hydrate formation/dissociation as well as the condition of thermodynamic equilibrium. The equations provide a complete description of hydrate dissociation in a uniform porous media in a one spatial dimension resulted in quantitative estimates for the time scale of hydrate releasing into the atmosphere.

SE49 Marine magnetics 35 years after Vine-Matthews-Morley discovery (in memory of D. Matthews)

Convener: Dyment, J.
Co-Convener: Kőrner, U.

Sponsorship: Inter Ridge

STRUCTURAL AND TEMPORAL VARIABILITY OF THE MAGNETIC LAYER OF OCEANIC CRUST UNDER CONDITIONS OF SLOW SPREADING

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The magnetic modeling has been performed to understand the origin of lateral and temporal variations in amplitudes of linear magnetic anomalies mapped in the typical slow spreading area in North Atlantic between 23 and 29 degrees N (Canary-Bahamas Geotransect). The geometry of models was postulated from seismic reflection data and the results of 3D gravity modeling. Effective magnetization of the crust has been evaluated by Parker's (1972) algorithm and by the method of adaptive reparametrization (Gorodnitsky et al., 1994) as well. The results are presented as a set of maps showing the lateral distribution of magnetic anomaly amplitudes and effective magnetization of the crust. Several transects present the magnetic models complemented with seismic crossections, density estimations and spreading rates Two models of thick magnetic layer of oceanic crust (serpentinite and gabbro) are discussed.

VINE-MATTHEWS-MORLEY ANOMALIES: FROM SATELLITE TO SUBMERSIBLE

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The Vine-Matthews-Morley anomalies have been originally recognized on surface marine magnetic data and represent the major piece of evidence to define the chrons of the geomagnetic polarity time scale. These anomalies are also observed on various other magnetic data recorded at different altitudes. Satellite magnetic data reveal anomalies which are better explained by the natural remanent magnetization of the oceanic lithosphere on the Cretaceous normal superchron and on period of dominant geomagnetic polarity. Deep tow and submersible data show the fine scale structure of geomagnetic polarity and intensity changes, which sustain the notion of cryptochrons. The Vine-Matthews-Morley concept is therefore valid for anomalies recorded at altitudes as different as 1 m to 400 km, for time resolutions of 10 ky to 50 my. The amplitude and shape of the anomalies at these different altitudes suggest a complex structure of the magnetized layer, which varies both among spreading centers with different rates and thermal states and along the same spreading center depending on the segmentation. Despite the generality of the concept, the notion of seafloor spreading isochron may need further consideration to take into account this variability and provide the bases for better paleogeographic reconstructions.

HOW DO SERPENTINIZED PERIDOTITES CONTRIBUTE TO MARINE MAGNETIC ANOMALIES?

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Marine geological and geophysical observations show that serpentinized peridotites are a major component of the oceanic crust formed at slow spreading ridges. Their contribution to magnetic anomalies is probably important but is not well known because the properties of individual samples may vary widely. We have studied magnetic properties of serpentinized peridotites from Leg 109 and 153 (Hole 670 and 920 respectively) located near the Mid Atlantic Ridge. Natural Remanent Magnetization (NRM), magnetic susceptibility (K), Koenigsberger ratio (Q), saturation magnetization (Js), saturation remanence (Jrs), coercive force (Hc) and remanent coercivity (Hcr) have been investigated. K and Js reflect the percentage of magnetite formed during the serpentinization, it depends on the serpentinization degree also on the Fer-partitionning between serpentine and magnetite. The samples from Hole 670 are characterized by an increase of their magnetic grain size with serpentinization. Magnetic grains of Hole 920 samples remain small whatever their serpentinization degree. NRM of samples from Hole 920 is about 15A/m, their average Q-ratio greater than 1 indicates that these rocks constitute a remanent magnetic source. Some samples from Hole 670 are similar but most of them are characterized by a weaker NRM (lower than 5 A/m). Their average Q-ratio is less than 1, indicating that these serpentinized peridotites are principally an induced magnetization source. We therefore show that magnetic properties of similarly serpentinized peridotites can vary significantly: from peridotites such as those from site 920 that are capable of carrying a strong remanent magnetization to peridotites such as most of those from site 670 that carry only a weak remanent magnetization.

VARIABILITY OF THE MAGNETIC ANOMALIES OVER THE SLOW SPREADING RIDGES AND THEIR INTERPRETATION.

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The Vine and Matthews hypothesis has allowed to model the oceanic magnetic anomalies over the all ridge system, whatever the spreading rate, using a simple symmetric model of series of reversed and normal magnetized blocks. However, along the slow spreading ridges (half rate $\ll$ 2 cm/yr), it is difficult to find such synthetic models which match quite correctly the observed magnetic profiles, in view of asymmetric spreading and related different shape of the same anomalies on either flanks. Detailed surveys of several sections of 0-10Ma old crust carried out over the Mid-Atlantic, Carlsberg and South-West Indian ridges, allow to improve synthetic model for a better anomalies indentification and reversals location. Frequently, a classical 2D model with small ridge jumps (around 10 km) enables to explain change of the anomalies shape, aswell as their asymmetric position. This result is supported by a method of maximum crosscorrelation of similar alligned fragments and drawing correlation figures, which allow to determine the best time and distance of the ridge jump. The resulting identification of magnetic anomalies allow to determine isochrons on both flanks. However the superposition of two conjugate isochrons is not accurate due to the distortion shape, and this misfit can be explained by a variable slope of the block limits coming from the 3D structure of the slow spreading ridges.

3D MAGNETIC MODELING ON SLOW-SPREADING RIDGES: IMPORTANCE OF END-EFFECTS NEAR DISCONTINUITIES

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Studies on slow-spreading systems showed a well-developed 3D architecture. Extrusive lavas which were previously considered as the main magnetic source layer exhibit a fast time-dependent decay, suggesting that the contribution of layer 2A decreases with age. Studies on rocks magnetic properties showed that peridotites and gabbros can strongly contribute to the signal. These characteristics require the use of a 3D modeling (Talwani's algorithm, 1965) which consider bodies of various shapes and magnetizations, including discontinuities, obliquity of lineations, many magnetization layers. Assuming a simplified geometry and a flat bathymetry, we performed the modeling on the SARA area (28.5°-30.5° N) on the MAR. We observe that data are better constrained with a two-layered source including extrusive lavas and gabbros. This modelling suggests that non-transform discontinuities need to be defined as transverse structures, in order to explain observed anomalies. End-effects are strong enough to explain variations of the amplitude of the central magnetic anomaly and its increase at segment endpoints. However the models do not explain observed positive anomalies within discontinuity traces. These models are being generalised by varying discontinuity offsets, field inclination, obliquity of magnetic lineations, and using observed bathymetry and crustal thickness. This should allow to moderate some results, inferred from the usual Parker's inversion, such as the abrupt increase in magnetization at segment endpoints.

AXIAL MAGNETIC ANOMALY AMPLITUDES ALONG THE MID-ATLANTIC RIDGE BETWEEN 20í AND 40íN.

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Corrected for the topography, spreading rate, latitude and lineation azimuth effects, axial magnetic anomaly amplitudes are compared with other data sets along the Mid-Atlantic Ridge (MAR) axis between 20í and 40íN. At a regional scale (>100 km), two long wavelength signals are located between 37.5í and 40íN and between 27í and 30íN. The magnetic high centered upon the Azores hot-spot at 40íN is associated with marked bathymetric, gravity, low seismic velocity and geochemical anomalies which suggest particular sublithospheric processes, deeper and more extensive partial melting and therefore a possibly thick Fe-Ti-enriched magnetic source layer. A similar process is proposed to explain the magnetic high centered at 29íN which is associated to weaker bathymetric and gravity features but to a large low seismic velocity anomaly and a marked intermediate wavelength geoid anomaly. At ridge segment scale, all but one of the 25 segments present higher amplitude at segment ends than at segment centers. Comparison with the range of the Mantle Bouguer Anomaly (?MBA) reveals a clear correlation with the range of amplitude (?A) and more complex relationships with median amplitude, amplitude at segment centers and at segment ends. Two different groups of amplitude variations are observed, "hotter" segments exhibit scattered amplitude at segment ends and grouped amplitudes at segment centers while the opposite is observed for "colder" segments. These observations support fractionation in the case of segment in a relatively hot state and presence of serpentinized bodies for segment associated with a coolest thermal structure as the major processes which control the axial magnetic anomaly amplitude variations.

SE50 Recent marine geological and geophysical investigation in the Mediterranean and Black Sea

Convener: Ergün, M.
Co-Conveners: Ivanov, M.K.; Woodside, J.M.

NEOGENE TECTONICS OF THE LATAKYA BASIN

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The Iskenderun-Latakia-Mesaoria Basin developed as an arcuate Miocene piggy-back basin above an ophiolitic thrust sheet, which links the Hatay and Troodos culminations via the Larnaka Ridge. To the north, the basin is bounded by the imbricate thrust fan of the Misis-Kyrenia Range. Thrusting ceased in the Messinian in the north and the basin subsided rapidly during the Plio-Quaternary, filling with a prograding delta succession above Messinian evaporites. The succession collapsed in an extensional fault fan detached in the salt, complemented by a salt-cored fold belt. The eastern boundary of the basin is defined by the offshore extension of the transtensional Amanos Fault zone. In Kyrenia Range and Mesaoria Basin thrusting continued until the Pleistocene creating small piggy-back basins with Pliocene growth strata. Rapid uplift and exhumation started in the Pleistocene. This interpretation of the evolution of the Mesaoria Basin contrasts with earlier models of Pliocene fore-arc extension.

SOUTHEAST PACIFIC TECTONIC EVOLUTION SINCE 33 MA: STEPWISE MIDOCEAN TRIPLE JUNCTION MIGRATIONS

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Based on oceanic plate tectonic reconstructions of the southeast Pacific ocean, major plate reorganizations are found to have occurred at chrons 6C (24 Ma), 6(o) (20 Ma), and 5A (12 Ma), with a smaller reorganization at chron 3(o) (5 Ma). The manner of plate boundary reorganization at chrons 6(o) and 5A (and possibly today at the Juan Fernandez microplate) included a sequence of rift propagation, transfer of lithosphere from one plate to another, microplate formation, and microplate abandonment. The sequence of events is called a stepwise triple junction migration because the location of the Pacific-Antarctic-Nazca (PAN) midocean triple junction jumped several hundred kilometers as a result of each reorganization. An example of a stepwise triple junction migration occurred at chron 5A when a ridge propagated 500 km northward from the Valdivia FZ system to the Challenger FZ, through Nazca plate lithosphere formed roughly 5 Myr at the Pacific-Nazca ridge. The PAN triple junction jumped northward 500 km as a result of this reorganization. The Pacific-Antarctic and Nazca-Antarctic ridges were each 500 km longer after the reorganization, with the Pacific-Nazca ridge 500 km shorter. The chron 5A reorganization included changes in spreading direction of the Chile and Pacific-Antarctic ridges.

AUTHIGENIC CARBONATE INCLUSIONS IN GAS SATURATEED SEDIMENTS OF THE BLACK SEA

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Active fluid venting and its surface manifestation (gas hydrates, carbonates and unique chemosinthetic microorganism) have been recorded in the North-Eastern part of the Black Sea during the TTR-6 cruise. Authigenic carbonates in a form of crust, nodules and fragile inclusions were found in the different intervals of sedimentary cores. Collected samples in thinsection, by X-Ray analysis and measurements of C and O stable isotope values were performed. High-Mg calcite, calcite, dolomite and botryoidal aragonite void-filling cements are common features of these carbonates. At two sites carbonates were presented mainly by ^{13}C enriched dolomite. Carbonates are marked by delta ^{13}C negative values in the range from –2.08‰ to–50.90‰ PDB and $\delta^{18}O$ –3.29‰ to –6.77‰ PDB.

Strongly ^{13}C depleted carbonates (from –27.60‰ to –50.90‰ PDB) occur inside distinct intervals where increasing of gas concentration were observed. The gas from these sediments revealed to be mostly methane (97-99%). Stable isotope data of carbonates can be interpreted as s result of mixture of the marine and methane derived carbonates.

TECTONIC SETTING OF THE LEVANT MARGIN

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The Levant continental margin off Israel, Lebanon and Syria is a passive margin that was formed during early Mesozoic by continental rifting. The morphology of the margin changes significantly from south to north. It partially reflects the deep crustal structure of the continental margin and the tectonic processes which are taking place over there. The continental margin is divided into two distinct provinces separated by the Carmel structure which extends northwest-ward from land across the continental margin into the Levant basin. Seismic refraction and gravity data indicate that in the southern province the transition from continental to oceanic crust is gradual and takes place tens of kilometers offshore, at the base of the continental slope. On the other hand, in the northern province the transition is rather sharp and takes place close to the coast. Magnetic anomalies are also of different patterns in the two provinces. The northern province of the Levant margin is seismically active and continuous seismic profiles indicate the existence of active faults in this region. The southern province is more stable. It is suggested that part of the movement between the Arabian plate and the Sinai plate is transferred to the northern province of the continental margin through faults in northern Israel and southern Lebanon, which connect the Dead Sea rift with the continental margin.

SOURCES OF ORGANIC MATTER IN PLIOCENE SAPROPELS FROM EASTERN MEDITERRANEAN : MOLECULAR AND SEDIMENTOLOGICAL APPROACH

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A series of Pliocene sapropels from ODP Site 969, located on the Mediterranean Ridge, were investigated for their extractable lipid components. The sapropels were extraordinary organic-carbon rich with values reaching 32.2%. The molecular composition of extractable lipids was dominated by alkyl diols and ketols, alkenones and sterols with less important amounts of n-alkanes and n-alcohols. The molecular data indicate that organic matter in sapropels is predominantly derived from marine algal sources. Nevertheless, the distribution of terrestrial lipids indicates a significant rise of land-derived influx during periods of sapropel formation. Additionally, stanol/stenol ratios suggest that anoxic conditions prevailed during the formation of highly organic-rich sapropels.
Sedimentological data show that the deposition of these sapropels is mainly related to climatic control, as most sapropels and carbonate cycles are dominantly controlled by earth-precession (# 22-kyr periodicity). Examination of smear slides shows that organic matter (OM) is mainly amorphous, with some vegetal fragments of continental origin. OM corresponds to high marine productivity, at least *pro-parte* from marine planktonic diatoms that are preserved within some sapropels.

SEISMIC EVIDENCE FOR SHALLOW GAS ACCUMULATIONS IN THE SOROKIN TROUGH (NORTH-EASTERN PART OF THE BLACK SEA)

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Single-channel seismic data, collected in 1996 on the Crimean continental margin (Black Sea) during TTR-6 Cruise has been analyzed. The study area is known for mud diapirism. At the cruise several mud volcanoes and multiple gas seeps were discovered. Gas hydrates were sampled from several mud volcanoes.

Multiple manifestations of gas occurrence and migration through the sediments, such as bright spots, acoustic voids, and acoustically transparent columnar disturbances, have been recognized on the seismic recordings. Two types of seismic inversion algorithms (maximum-likelihood inversion and model-based gradient inversion) have been applied to the data. This allowed for estimating seismic impedance and velocity fields and facilitated more reliable distinguishing of gas accumulations. Local zones of significant decrease in seismic velocity observed indicate presence of free gas trapped in sedimentary pile. Some of these zones are related to the bright spots located on the flanks of diapiric structures.

NEOGENE TECTONICS OF THE CILICIA-ADANA BASIN

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The Cilicia-Adana basin developed as an arcuate Miocene flysch-filled foredeep across an ophiolitic suture. Tortonian molasse marks inversion, with deposition in piggy-back basins on a trailing imbricate thrust fan. Thrusting ceased in the Messinian in the east but continued during the Pliocene in the south. Exhumation created the Kyrenia-Misis high, marking the southern boundary of a Messinian evaporite basin. During the Plio-Quaternary the basin subsided rapidly, filling with a prograding delta succession, while extensional faults grew on the northern flank of the Kyrenia range. They cut Miocene basement and may be linked at depth as an extensional reactivation of Miocene thrusts; their configuration suggests transtension, probably related to the westward tectonic escape of the Anatolian microplate. Within the basin, collapse of the prograding delta succession led to the formation of an imbricate extensional fault fan, detached in the Messinian evaporites and accommodated by a still active salt-cored fold belt.

SONAR AND SEISMIC INVESTIGATIONS IN THE SOROKHIN TROUGH (SE CRIMEA, BLACK SEA)

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The Black sea occupies an oval basin between the folded Alpine belts of the Caucasus and Crimea Mountains to the north and Northeast and the Pontic Mountains to the south. The mechanism of immense subsidence has given way to the deposition of thick sedimentary sequence reaching up to 14-15 km. Mud volcanoe features have been observed in the abyssal plain of the mid-Black Sea basin towards the southern and southeastern margin of the Crimean peninsula. The main objective of this paper is to describe the seafloor features related to the mud volcanoes and to the identify their origin with respect to the neotectonic processes. Detailed investigations were carried out across faults, controlling hydrocarbon fluid escapes, and fields of gas hydrates in the Sorokhin Trough (SE Crimea). Six High Resolution Seismic Profiles were observed simultaneous with recording of side scan images (MAK-1 and Multibeam Simrad EM-12S) bathymetric surveying in order to define whether faults, diapirs, mud volcanoes, hydrocarbon fluid accumulation (bright spots) structures are accompanied by hydrocarbon seepage. The structure of upper part of the sedimentary cover was analysed based on the subbottom profiler and seismic data. The lithological composition of the bottom sediments was correlated using sampling with gas content in order to reveal the relationship between the lithological types and the degree of gas saturation.

SOME GEOLOGICAL RESULTS AND EVOLUTION OF THE WEST BLACK SEA BASIN

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The last ten years mark considerable progress in studying the geology of the Black Sea by geophysical methods. It is discovered that it consists of two paleobasins - Western and Eastern. In this respect the contribution of seismic data and their seismostratigraphic analysis is of great importance. Some problems of depth structures and evolution of the West Black Sea Basin are treated in this paper on the basis of complex interpretation of seismic, gravimetric, magnetic and geothermal data. The West Black Sea Basin is deeper and larger than the East Black Sea Basin. Besides it is caracterised by shallow position of the M. boundary, deeply laid preuppercretaceous basalt fundament and thick indeformed cretaceous-cenozoic sediments.

GEOPHYSICAL DATA FOR THE ANAXIMANDER MOUNTAINS

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The Anaximander Mountains lie at the junction between the Hellenic and Cyprus arcs. The mountains are separated by faults and are undergoing independent movement and deformation resulting from relative northwestly movement of the African plate with respect to the Aegean and Anatolian microplates. Gravity results indicate that there a major crustal discontinuity running directly through the middle of the mountains and that the western peaks undercompensated crustal loads and the eastern peaks overcompensated. The magnetic data of the region is rather patchy and this suggests a complex block structre. Multibeam bathymetric data indicate five different geological provinces: a fold belt resulting from northeastward compression of Antalya Basin sediments by the mountains. the eastern and southern mountains. the western mountains. Finike Basin. and a large tongue of gassy sediments which seems to have flowed out over the Finike Basin from between the western and southern mountains. Messinian evaporites appear to be absent (except in the Antalya Basin and to the south) implying that the basin formed since the Miocene. Mud volcanoes found within the eastern mountain are probably a result of overpressuring by gas in deeper sedimentary rocks. possibly related also to the compression.

NEOGENE TECTONICS OF THE CYPREAN ARC REGION

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The Cyprean arc lies on the boundary between African and Anatolian plates. It links the Hellenic arc to the west with the East Anatolian transform margin to the east. The arc has only diffuse seismicity and no active volcanism, arguably because of incipient continental collision. We present results of 4500 km of multi-channel seismic reflection data collected by us, and integrated with a database of some 10.000 km of additional seismic profiles. Interpretation is illustrated in detail in accompanying poster papers, which focus on the fore-arc basins of Cilicia-Adana, Latakya-Mesaoria. Each of these basins and the Antalya basin to the west has a distinctive Neogene history related to its position in the arc complex, and the changing direction of the convergence vector. Oblique convergence is partitioned between compressional and strike-slip faulting in different ways, and extensional fault systems accompany shelf and crestal collapse.

QUATERNARY SEDIMENTARY PROCESSES ON THE NORTHEASTERN MARGIN OF THE BLACK SEA

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The Sorokin Trough and the Pallas Uplift, which are located on the northeastern margin of the Black Sea, were studied in 1996 during the 6th Training-through-Research Cruise using a set of geological and geophysical methods.
The northeastern continental margin of the Black Sea is covered by a thick sedimentary sequence, in which Maikopian deposits (Oligocene-Lower Miocene) attain a thickness of more than 5 km (lower seismic unit), and Pliocene-Quaternary deposits is more than 2.5 km (upper seismic unit).
The upper unit in the most part of the study area is represented chiefly by Quaternary sediments of the paleo-Don/Kuban Deep-Sea Fan. Three periods of the activity of this fan during the low sea-level stands of the Black Sea can be supposed basing on seismic data. In the western part of the study area there is the small Yalta Deep-Sea Fan. Periods of activity of this fan differ from those of the paleo-Don/Kuban Deep-Sea Fan and coincide with the sea-level rises. The Yalta Deep-Sea Fan developed as a result of the melting of the ice cap in the Crimean Mountains. Diapiric folds formed by Maikopian clay in the Sorokin Trough are expressed in the seafloor topography and act as the natural barriers for turbidity currents. The western recent channel-levee complex of the paleo-Don/Kuban Fan seems to be controlled by the underlying structural trends.

SEDIMENTOLOGY OF PLEISTOCENE OF THE BLACK SEA IN GEORGIA

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The Pleistocene sediments are wide-spread in the Georgia Black Sea-side. These sediments are observid in orogenie zones (Caucus. Ajara-Trialeti) as a kind of nautical terraces, which are disposed at different gypsometric levels.
The Pleistocene sediments of Kolkheti lowland are immersed at rather considerable depth.
Eustatics of the World Ocean and corresponding by the Black Sea eustatics Pleistocene and neotectonie movements as well participated in the formation of the region understady. Both these processes are clearly established in vertical alternation of faunistically stratified marine terrace facies. And in vertical section replacement of marine sediments by continental ones or break in sedimentation point to high sate of neotectonic movements.
Absolute indices of marine terraces are complicated due to neotectonic movements and don't corespond to the sea level change in Pleistocene.

GEOTERMICS OF THE BLACK SEA BASIN

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The Black See basin is a deep depression situated in the Alpine folded belt. The total thickness of Crateceous-Quaternary sediments in the central part reaches 14-18 km. The Earth crust thickness is reduced to 22-28 km. In the Black Sea basin more than 500 heat flow density (HFD) determination have been made. Low HF D (20-40 mW/m2) is dominated. Zones of high HFD are distinguish in the basin periphery and along the Trans-Black Sea fault. The efect of crustal structure, sedimentation, heat generation and near-floor temperature variation influence has been estimated based on numerical modelling of heat transfer condition. The main distortions are associated with Pliocene-Quarternary sediments. The corect HFD are 50-55 mW/m2 in the West Black Sea basin and 40-5- mW m2 in the East Black Sea basin. The mantle HFD is 30-40 mW/m2. A 2-D geothermal models of earth(s crust have been set up for several profiles. On the base of HFD data lithosphere thickness and opening age have been estimated.

MCS PROFILES IN A ZONE OF INCIPIENT COLLISION BETWEEN AFRICA AND EURASIA, EASTERN MEDITERRANEAN

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MCS lines across the collision zone between Africa and Eurasia provide insight into the deformational pattern in a scenario of microplate tectonics. A set of seven lines oriented subparallel to the presumed direction of plate convergence are tied by a cross-cutting, WSW-ENE-striking line. This widespread coverage reveals the variation in both the geometry of the plate boundary as well as the thickness of sediments. Careful processing provided satisfying images with prominent reflections as deep as 15 kilometers. Whether the top of the basement is reflected by this reflector is questionable. Pre-stack depth migration of the lines imaged profound variations in thickness of the basin fills between the predominantly sediment-free topographic highs (Larnaca, Latakia and West Tartus Ridges). In the Phoenician Basin south of Cyprus, up to 14 km of sediment has accumulated since the mid-Mesozoic. Moving northward, the sedimentary sequence in the Cyprean Basin is between 2 and 3.5 km thick (increasing to the East), while further north in the Latakia Basin up to 5 km thick, undisturbed sediments are observed. All sediment successions illustrate the presence of Messinian evaporites (tens of meters to more than 1 km in thick). The entire study area is characterised by sets of strike slip faults which relate to the major tectonic lineaments on land (e.g. Dead Sea fault, Anatolian faults, etc.) and which intersect both the ridges and, less frequently, the basins. Moreover, both compressional (imbricate thrusting, folding) and extensional (normal faulting, block faulting) structures are abundant. The vicinity of the deformation front suffers intense faulting and dewatering, and the geometry of the plate boundary varies considerably along strike. These variations most likely relate to continental fragments presently colliding with Cyprus, namely the Herataeus and Eratosthenes Seamounts.

AVA-ANALYSIS ACROSS THE WESTERN MEDITERRANEAN RIDGE

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Seismic reflection coefficients depend on the impedance contrast and the reflection angle. For angles θ less than 30° the following first order approximation for the P-wave reflection coefficient Rp exists:

$$Rp(\theta) = Rp(0)+[Rp(0) - 2Rs(0)] \sin^2(\theta)$$

For horizontal layering NMO-corrected CMP-Gathers can be transformed into Common Reflection Angle gathers, for which the source-receiver distance has been replaced by the common reflection angle. If the transformation is based on the squared sine of the angle, a least-squares approximation of the amplitudes yields the P-wave and S-wave reflection coefficients for every time sample. Synthetic data as well as data of the IMERSE-Project have been analysed and the results are presented here.

GAS-CHARGED SEDIMENTS BENEATH THE BLACK SEA SHELF

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High-resolution seismic reflection profiles collected by the Moscow State University and P.P. Shirshov Institute of Oceanology evidence that Golocene gas-charged-sediments upto 10-12 m thick are widespread at a depth of 5-10 m bsf on the western, north-eastern and Caucasus shelves of the Black Sea. These areas are quite large in size. On the western shelf, the gas-charged sediments zone is a few tens kilometers wide and several hundreds kilometers long. Its western and eastern boundaries are limited by isobaths of 35-40 m and 80-90 m respectively. On the Caucasus shelf, this area is limited by isobaths of 10-15 - 45-50 m. No causal relationships between the areas and regional tectonic framework are revealed. Piston core data evidence that the gas-charged sediments abound with organic carbon (1-3% for lower part of novochernomorsky unit and 3-5% for drevnechernomorsky unit). The organic substance is considerably humus-sapropelic detritus. Shallow gases beneath the Black Sea shelf seem to generated as a result of intense biochemical decomposition of the substance.

NEW DATA IN EASTERN MEDITERRANEAN FROM THE PRISMED II SURVEY (R/V ATALANTE).

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The Prismed II cruise, onboard the RV Atalante (Feb 98) has allowed to survey five large areas of the deep Levantine basin in Eastern Mediterranean. Continuous swath mapping, bottom acoustic imaging, seismic reflection profiling together with magnetic and gravity measurements have been collected in the following morphostructural domains:
- The central Mediterranean ridge, where ongoing incipient collision is believed to occur between southern Crete and the passive libyan continental margin and where large provinces of mud diapirs and volcanoes are known.
-A wide area of the Eastern Mediterranean Ridge where the deformational style partly results from oblique convergence processes between Aegea and Africa
- the Florence rise, which constitutes a structural compressive link between the Mediterranean Ridge and the Cyprus Arc.
- the Southern Cyprus Arc, particularly the Erathostene seamount which is progressively entering in collision with the Cyprus margin.
- finally the Nile deep sea fan, characterized by a huge sedimentary pile and diapiric deformations
We present and discuss parts of the preliminary results from this cruise in the ligth of previous investigations.

ESTIMATING IN-SITU PORE PRESSURE AND FLUID FLOW BY MODELLING PUPPI PRESSURE DECAYS FROM THE MEDITERRANEAN RIDGE

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We modelled data of porewater pressure measurements that were recorded with the free-fall Pop Up Pore Pressure Instrument (PUPPI) during the MEDRIFF project. The cylindrical finite-element models allow for variation of the sediment permeability in both the radial and vertical directions. Estimation of the ambient pressure is usually achieved by extrapolating the recorded pressure history in the $1/t$-domain if equilibrium pressure has not been reached. Comparison of extrapolation with the model results shows that the extrapolation may lead to inaccurate estimation of the ambient pressure if radial compaction has not been taken into account. In addition, lateral subsurface flow could be detected. Two pressure histories recorded during the MEDRIFF project that had come to equilibrium, provided a test of the accuracy of the models. The measurements required significant correction for variation in the salinity of the porewater caused by the Messinian evaporites. The model results indicate close to zero (some mm/year) downward flow at the location of the PUPPI deployments.

STRUCTURE OF THE BLACK SEA FROM THE GEOPHYSICAL DATA

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Observing and analysing the extensional tectonics of the Black Sea and of the Mid-Black Sea ridge, it is possible to show that this region was affected by two main rifting phases(Middle Jurassic and the upper part of the Lower Cretaceous). During the last geodynamic process, the opening of the deep Black Sea took place as a consequence of the formation of two back-arc basins behind the W and E-Pontides. The W-Black Sea basin evolved to the stage of complete crustal opening with a basaltic basement progressively younger from N to S. At the same time, the E-Black Sea basin evolved to the stage of a very thin continental crust affected by numerous listric faults and block-tilting. The deep E and W-Black Sea basins of the Black are marked with two elongated Bouguer gravity anomalies reaching up to 140-180 mGal. Gravity data interpretation results gave very similar results as obtained by the deep seismic studies in the Black Sea with up to 15 km sediment thicknesses. Magnetic anomalies of the deep Black Sea and the surrounding areas are distinguished regionally. The E-Black Sea basin has dominant SE-NW trending magnetic anomalies extending from Batum to Crimea in line with the Caucasus trends. The southern side of Black Sea along the Turkish coast is dominated by short wave-length magnetic anomalies.

SEABED STABILITY RELATED TO GAS PHENOMENA

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The occurrence of gas hydrates, hyperconcentrated dissolved gas and free gas in cohesive sediments, like mud and soft clays, plays an important role in the stability of the seabed of for instance continental slopes and river fans on continental shelves. Given the fine pore size distribution within cohesive sediments, conditions may be such, that much more gas (especially methane and carbon dioxide) can be dissolved in the porewater, than compared with free water, due to capillary condensation effect. The equilibrium between dissolved gas, gas hydrates and free gas in bubbles is at high free gas contents indifferent stable due to the underconsolidated state. The stability can be triggered by events like storm surges and earthquakes, resulting in bubble growth, cracking and bubble coalescence. The subsequent gas release can induce landslides, turbidity currents and tsunamis. During gas release also local rapid consolidation of the sediments takes place, and local depressions are formed. The outflow of gas and porewater will be local, yielding vertical discharge channels, like pockmarks (small scale) or mud volcanoes (large scale).
In the paper the involved processes are described theoretically and experimentally, and applied for stability analysis of the seabed like landslides, pockmark stability and differential.

THE DANUBE-DNIEPR DEEPSEA FAN COMPLEX: MORPHOSTRUCTURE AND EVOLUTION

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Eight seismic sequences have been distinguished and mapped on the continental slope and in the deep basin of the northwestern Black Sea. The two lower sequences consist mainly of unchannelized mass transport deposits, while the six upper sequences with their typical channel-levee systems, and overbank and mass transport deposits build up the deepsea fan. The fan complex can be subdivided into the Danube fan and the so-called Dniepr fan, of which the latter probably comprises sediments delivered by the rivers Dniepr, Dniestr and Bug. Different types of mass transport deposits predominate in each fan: slump deposits are prevalent in the Dniepr fan, while sediment slides and debrites are the most abundant in the Danube fan.
Relative onlap curves for eight shelf locations have been constructed. By estimating the subsidence due to thermal relaxation and sediment load, as well as vertical displacements due to faulting, a regional "eustatic" sea level curve has been established. The six upper sequences were then correlated with this sea level curve and the global oxygen isotope stages, yielding an age estimate of ca. 900 ka for the deepsea fan complex. The computed, decompacted average sedimentation rates range between 130 and 225 cm/ka.

THE IMPORTANCE OF THE MARMARA SEA GATEWAY IN PALEO-OCEANOGRAPHIC EVOLUTION OF THE AEGEAN SEA

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Interpretation of single-channel and Huntec deep-tow profiles demonstrates that the Marmara Sea experienced small amplitude (-70m) fluctuations in sea-level during the Quaternary, limited in magnitude by the sill depths of the Dardanel and Bosphorus Straits. During the last glacial maximum, the sill depths of the Dardanelles and the Bosphorus forced a staircase of water levels in the region from about -35 m in the Black Sea to about -70 in the Marmara Sea to about -120 m in the Aegean. The global sea-level curve shows that, at 11.000 and 9.500 yrBP correlates remarkably well with the onset of the deposition of S1 in the Aegean Sea. The timing of the development of S1 in the Aegean Sea, as well as S1 of the Mediterrenean, is interpreted to coincide with the time of rapid trangression across the southern shelf of the Marmara Sea and contemporaneous vigorous outflow of low-salinity surface waters transiting the Marmara Sea gateway derived from melting of northern European ice sheets.

SE51 Structures and processes in sedimentary fans

Convener: Uenzelmann-Neben, G.
Co-Convener: Droz, L.

THE NILE DEEP-SEA FAN : PRELIMINARY RESULTS OF THE PRISMED II CRUISE (R/V ATALANTE).

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Up to now, the Nile Cone, despite of its important size, remained poorly known. The rough exploring methods available on this deep-sea fan, such as single channel echo-soundings and deep penetrating seismic profiles, did not allow to clearly identify any specific feature now commonly described in most of the deep-sea fans such as main physiographic divisions, networks of channels, sedimentary lobes, growth-faults morphology etc., or contrasted acoustic facies indicating significant growth pattern (stacked and shifting sedimentary bodies).
During 15 days, the "Prismed II" cruise of the R/V Atalante permitted to study the Nile Cone, thanks to swath multibeam bathymetric profiles, acoustic imagery (with Simrad EM 12 dual), high resolution seismic profiles, magnetometry and gravimetry.
The preliminary results of this cruise are presented and discussed.

STUDY OF DYNAMIC OF MUD BANK ALONG THE GUIANA COAST

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This poster presents the contribution of Orstom to the PNOC (Programme national d'oceanographie cotiÞre) on dynamic of mud banks along the french Guiana coast. The sediments yield by the river Amazon can remain suspended in water or settle and form mud banks. They are transported from the mouth of the river to the Caribbean Sea, affecting severely the ecological equilibrium of the coastline. The present study aims to investigate the dynamic of mud banks along the coast of Guiana. Nowadays, it exists six mud banks along this coast, each of an approximate volume of three milliards cubic meters. It had been evaluated that their average propagation rate is about 900m per year, with seasonal and local variations. The interactions of combined hydrologic phenomena, such as wave, currents, together with mechanical behaviour of the material are responsible for the observed dynamics (i.e. fluidisation, erosion...). The planned study consists of the achievement of in situ measurements, carried out simultaneously with the development of one and two dimensional models.

SALT TECTONICS GROWTH FAULT PATTERN IN THE GULF OF LION PLIO-QUATERNARY/FRANCE

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Extensional tectonics diven by the Messinian salt layer flow and its associated structures have long been reported in the literature of the Gulf of Lion. The mapping of the fault trends, though, has not been achieved up till now due to inconsistent bases of seimic data. The present study aims then to mapping this growth faults pattern and investigate its role as a possible controlling factor for the Plio-Quaternary progradation, based on closely spaced industrial multichannel seismics. Preliminary results show that the trends of these structures seem to be controlled by the general slope orientation, being parallells to the slope gradient. The fault planes of the middle slope, present a general E-W trend along the south Provencal margin, changing to a NE-SW direction in the vicinities of the Canyon Marseille following the bulging associated to the Rhone Deep-sea fan., to reacquire a E-W direction on the main axis of the fan progradation. Towards the Camargue margin a SE-NW direction is observed, before turning to a general N-S trend all along the Roussillon and Catalan margins. As for the distal faults in the deeper basin, a ENE-WSW trend is observed according to the general isobath orientation. Other structures like rollover anticlines, observed along the fault planes, induce importante local thickness variations in the Plio-quaternary sequence related to the rotation mechanism. As well as that, antithetic faults create some graben-like structures giving rise to topographic depressions that seem, at times, to trap channel systems complexes.

CELTIC DEEP-SEA FAN (WESTERN EUROPE): ARCHITECTURE AND SEDIMENTARY EVOLUTION

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The Celtic Deep-Sea Fan deposited as a broad radial turbiditic accumulation at the base of slope of the Celtic Margin (Western Europe). The main feeding paths for detritic sedimentation are two canyons of the margin : the Whittard Canyon to the west and the Shamrock Canyon to the east.
Morphological and geometrical results presented are based on the analysis of data collected during two recent cruises (SEDIFAN), including EM12 multibeam swath bathymetry and acoustic imagery, high resolution 6 channels air-guns seismics, and very high resolution PASISAR seismics.
The present-day fan is asymmetrical in its upper part. It includes a thick undulated western levee developped at the mouth of Whittard Canyon and channel, merging to a symmetrical, radial sandy body that shows several successive shifted depocenters.
Seismic analysis indicates that the present-day morphology does not reflect ancient physiography, and that there has been a drastic change in feeding ways, about half of the thickness of the turbiditic accumulation being related to sedimentary input brought by the Shamrock Canyon.

TURBIDITES OF THE WESTERN GOLFE DU LION: RELATIONSHIPS BETWEEN PYRENEO-LANGUEDOCIAN AND RHONE INPUTS

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Recent CALMAR cruise onboard the R/V l'Atalante, surveyed the westernmost part of the Golfe du Lion, using EM12 multibeam swath bathymetry and acoustic imagery, 3.5 kHz profiling, very high resolution sparker seismics (shelf sector), high resolution 6-channel air-gun seismics (slope and basin sectors), and piston and vibro corings.
The area surveyed extends from the outer shelf to the basin, receiving sedimentary inputs from various sources. Main sedimentary input to this part of the basin is the Petit-Rhone Canyon and related neochannel to the east, canyons and intercanyon areas to the north, pyreneo-languedocian canyons to the west and possibly the La Fonera Canyon to the southwest.
Sediments from this complex system are imbricated at the base of slope. Western canyons, with several successive courses, are grouped in a converging system that deposited a thick sedimentary body affected by large sediment waves. These turbidite deposits are covered by a broad transparent debris flow with multiple sources. The last sedimentary event seems to be the deposition of the neofan but precise relationships between gravity deposits have still to be established.

A high-resolution reconnaissance seismic survey in the Bengal Fan

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The largest submarine fan of the world - the Bengal Fan - and the connected eastern Bengal Shelf were the scientific targets of the RV Sonne cruises SO125/SO126 from October to December 1997. The dataset includes more than 8000 km of digital sediment echosounder (Parasound) and bathymetric data (Hydrosweep) as well as 3500 km multi-channel seismic data. Since two different seismic sources (GI-Gun and watergun) with a different frequency content were triggered in an alternating mode, alltogether four different datasets were collected. The particular scientific objectives were: (1) Sedimentat transport from the Ganges-Brahmaputra Delta across the shelf. (2) Seismic stratigraphy of the Bengal Shelf. (3) General depositional processes on the Bengal Fan. (4) Downfan development of the modern channel-levee system. (5) Sedimentation history at DSDP Leg XXII, Site 218 in the lower fan. (6) Relationship of meander geometry and depositional terraces within the channels. (7) Channel shifting and channel jumping. We will present examples from all datasets and first results.

SYNTHESIS OF RESULTS FROM ODP LEG 155, AMAZON FAN

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Amazon Fan aggraded during lowstands of sea level and switched depocentres during major highstands. Channel avulsion occurred every 3-8 ky during lowstands and only one distributary was active at one time, although some turbidity currents spilled over into abandoned channels. Depositional rates on levees of active channels reached 25 m/ky with a turbidity current every 2-8 y. Thick-bedded sands in units up to 25 m thick were formed following avulsions on the middle fan and extend downfan to form the greater part of the lower fan. Coarse-grained deposits on the lower fan, which resemble those of many "sandy fans", and thick muddy sequences on the middle and upper fan formed simultaneously. We cannot recognise a "slope fan" or "basin-floor fan" at different stages in the sea-level cycle. The lithofacies characteristics of channel, levee, and lobe deposits have been defined. Changes in silt abundance in levees define fining-up sequences, but cannot be ascribed solely to autocyclic changes or effects of sea-level change and may in part result from climatically-controlled changes in Amazon discharge. Major mass-transport deposits were characterised lithologically.

CONTROLS ON FAN ARCHITECTURE AND DEPOSITS BY TURBIDITY CURRENT INITIATION PROCESSES

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Deep-sea fans are deposited from turbidity currents initiated by (a) frequent sediment failure in high-sedimentation rate environments; (b) less frequent failure, generally induced by earthquakes; (c) hyperpycnal flow from medium and small, bedload discharge rivers and from meltwater at ice margins; (d) storm flushing of continental shelves and canyons. Several case studies with new data are presented for these various types, including a high-resolution deep-towed boomer investigation of sandy Hueneme Fan and new findings on Laurentian and Amazon fans. Various architectural features can be observationally and conceptually linked to different types of initiation mechanism. Highly asymmetric levees and prominent sandy lobes, implying inefficient sand transport, result from hyperpycnal flow. Evolved meandering systems result from frequent sediment failure and they efficiently transport sand to the lower fan. Changing types of sediment source result in complex channel patterns and facies distribution, most clearly seen on Laurentian Fan where initiation types (a), (b) and (c) occur at different times during glacial cycles. [K. Skene, W.R. Normark, R. Hiscott, M. Deptuck and the ODP Leg 155 Scientific Party contributed data and ideas to this synthesis].

DETAILED MORPHOLOGICAL ANALYSIS OF DEEP-SEA MEANDERING CHANNELS: EXAMPLE OF THE ZAIRE (CONGO) FAN CHANNEL.

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The Zaire turbidite system is known to be presently active and fed by turbidity currents generated during flood periods of the Zaire River and by sand brought to the canyon flanks by the northward flowing littoral drift. This turbidite system can be considered as a modern analog for systems mainly active during lowstands of sea-level and constitutes an original model, intermediate between the large inactive muddy fans and the smaller active sandy fans.
Most of the Zaire fan channels are strongly meandering, with morphologies showing analogies with both fluvial and other deep-sea channels of high efficiency, mud-rich turbidite systems, such as the Amazon Fan.
Detailed morphological analysis of the modern channel, realised from EM12 multibeam swath bathymetry data collected during GUINESS cruises (IFREMER/EEP) over the upper and middle fan, indicates that the modern channel is presently or has been affected by erosional processes with possible limited overflow of turbidity currents. This erosion is responsible for a basinward shift of physiographic domains (upper and middle fan), reflecting a present-day prograding tendency of the entire turbidite system.

SE51

SEISMIC ARCHITECTURE OF A SMALL DEEP-SEA FAN (EAST CORSICA MARGIN, WESTERN MEDITERRANEAN)

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Coarse grained small turbiditic systems had received relatively little attention in the literature, compared to large well-known muddy deep-sea fans. However they have a great economic importance as petroleum reservoirs.
Recent detailed bathymetric maps combined with 3.5 kHz echosounding profiles analysis allow to precisely outline, along the East Corsican margin, a series of present small fans of varying sizes (5 km to 30 km in length and width), some of them coalescing. At the base of the slope, the canyons become progressively more depositional, displaying typical channel-levee features. As the channels become less steep, they divide into several lateral branches down to a distal area where no more channels are visible. The 3.5 kHz profiles across the distal parts of the fans show very reflective facies (no penetration), suggesting overspread of sandy deposits. Cycles of progradation and retrogradation of the suprafans on the slope are observed and each single fan body tend to occupy the lows created by the previous units.
We are able to map in three-dimensions the turbidite channels, the levees and the distal deposits for almost 6 successive turbiditic systems. This work opens the way to a very detailed sedimentological study of such small sandy fans, dealing with the processes of transport and deposition of turbidites and trying to predict the sand depositional pattern in such typical sedimentary environments.

TERRESTRIAL ORGANIC CARBON ACCUMULATION ON THE AMAZON DEEP SEA FAN DURING THE LAST GLACIAL SEA LEVEL LOW STAND

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New piston cores recovered during R.V. Meteor cruise 16-2 detail modern areal distribution of organic carbon, carbonate, stable organic carbon isotopes and depositional processes on the Amazon Deep Sea Fan. In addition up to 300 m long cores recovered during ODP Leg 155 allow evaluation of temporal variations of these parameters onto the Amazon Fan. Accordingly, we herein present new evidence for the very rapid change of Fan depositional processes and organic carbon source at times of sea level change revealed all over the Fan. Our results demonstrate that organic carbon accumulation on the Amazon Deep Sea Fan is controlled by glacioeustatic sea level oscillations. Authochthonus marine organic matter dominates during interglacial sea level high stands whereas during glacial sea level low stands terrigenous organic carbon (terr.OC) is channeled directly through the incised Amazon canyon to the Fan. Glacial sediments of the Amazon Fan stored about 73 Gt terr.OC in 20.000 years (or 0.0037 Gt terr.OC per year or 5-7% of the nowadays riverine organic carbon discharge); which is about the same amount of terr.OC the Amazon shelf stores today (0.0031 Gt terr.OC per year or 4 to 6% of the riverine carbon discharge).

NEOGENE SEDIMENTATION HISTORY OF THE CONGO FAN

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High-resolution seismic reflection data were interpreted to develop a model for the Neogene sedimentation in the Congo Fan area. Since it was possible to identify two reflectors representing the marine isotope stages 6 and 12, a distinction between the Early and the Late Quaternary was made possible. We observe a single sediment source system during the Late Paleogene/Early Neogene gradually changing into a two sediment source system in the Late Neogene. Since the Late Quaternary the Congo River has been the prevailing sediment source. Additionally, the evolving Benguela Current modified the system and led to a high biogenic productivity.

Indications for a tectonic control of the Congo Canyon have been found in the distribution of sedimentary units and the unit thicknesses.

HOLOCENE FJORD SIDE-WALL FAN DELTAS IN KONGSFJORDEN, SPITSBERGEN

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ABSTRACT

During the Holocene a series of fan deltas were developed along about 5 km of a fjord side wall in Kongsfjorden, Spitsbergen following deglaciation of the fjord. Accumulations on the deltas were buttressed by thrust-controlled platforms in the bedrock of the fjord side wall which allowed sedimentation to build out from the shoulder of the fjord and down the steep side wall. During the increased sedimentation associated with the glacier advances of the Little Ice Age a major failure occurred of part of the delta system which led to slumping of sediments to the fjord floor. Modern sedimentation on the individual delta fronts consists of cones of swales and ridges of gravels and sands with zones of creep terracing and minor scarps which occur parallel to the bathymetric contours at the break of slope of the fronts. The uppermost parts of the delta fronts are much disturbed by iceberg plough turbation. On part of the delta complex the creep terraces pass into a shallow trench which is continuous over about 1200 m of the delta front. The end zones of the trench exhibit transtensional movement towards the central zone which shows evidence of developing down slope sediment movement. It is proposed that the trench is the headwall break-away zone of an incipient slide failure. Catastrophic failure of this slide might cause a giant wave and seiching in this confined part of the fjord which has the potential for damage and loss of life in a nearby community.

SE52 Spontaneous globally synchronized variations of physical parameters (co-sponsored by G)

Convener: Rokityanski, I.I.
Co-Conveners: Denis, C.; Varga, P.

INVESTIGATION ON THE EFFECT ANOMALOUS DAILY DYNAMICS OF LOCAL GEOPHYSICAL FIELDS WITH THE AIM OF STUDY OF EARTHQUAKE PREPARATION AND REALIZATION PROCESSES

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In the present work the dynamic model of geological medium is considered, which reflects the fundamental natural peculiarity of the Earth, its non-closed nature i.e. its being opened for continuously acting exo- and endogenetic natural physical forces of global scale. According to this model, the geological medium consisting of massifs of rocks with invariable in time geophysical properties (energy-passive zones) and of areas with varying properties which vary in time with external physical effects of global scale (energy-active zones). As the longest periods of external physical influences transfer into the shortest ones, the medium is localized where the geophysical characteristics of rocks are changed from the global scale (over the whole volume of the Earth) at t=1018 s to the local one which corresponds to the length of X-ray wave at t=10-18 s. Therewith, the form of geophysical parameter alteration is various: from predominantly non-reversible to predominantly reversible. The dynamics of geophysical properties of geological formations, being excited by external physical forces of global scale and changing periodically within a wide range of time t, initiates corresponding dynamics of local geophysical fields, observed over them. It carries a valuable geological information, in particular, on the earthquake preparation and realization processes in seismically active zones.

SOME CHARACTERS OF VARIATIONS OF THE GEOLOGICAL OBJECTS' WEIGHT

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In this paper we consider variations of the such fundamental physical property of a real object as its weight. We controlled usual behaviour of the weight of each of the 18 geological objects (crystals, minerals, rocks and other) during 375 days. As it was shown, the time series of the object's weight is the fractal one. The objects with the same chemical composition proved to be characterized by the identical values of D — D denotes the fractal dimension of the curve that is given by a sequence of observations of the object's weight — even if the sequences described different behaviour. Using the methods of the fractal geometry in the light of the space-time physics (note, although the fractal geometry constructed as the geometry of natural objects, it ignores the four-dimensionality of the physical reality) we determine the fractal dimension F of the temporal structure and discuss its physical meaning. Behaviour of the value F as a function of the number of observations can point out the difference between the temporal structures of the such real objects as the 'geological objects' and, for example, the 'room conditions' (indoor temperature, air pressure, relative humidity). In the first case (time series describe dynamics of existence of the natural objects) $F \to 1$, in the second case (such real object is absent in space-time) $F \approx 0$.

THE WAVE EQUATIONS FOR OSCILLATOR WITH PLANK'S CONSTANT AND FORCE QUANTUM

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The model of oscillator with mass m in slowly rotating coordinate system is considered. The expression for potential energy of oscillator $U = mw^2x^2/2$ is symmetric with respect to angular frequency of rotation w and radius of rotation x. Provided that in case of small w not the mechanical angular momentum mwx^2 is quantisied, but force mw^2x, the wave equations of mass motion are examined. The spectrum of values of oscillator energies $\mathring{A}_n=\acute{I}\tilde{o}(n+1/2)$ is obtained, where $\acute{I}$ - has the meaning of a force quantum, $n = 0, 1, 2...$. Theoretical estimate for $\acute{I}$ is $(10^{-36} - 10^{-37})\ N$. This estimate is obtained from an observational cosmology. The presented model has a methodical sense as it permits to derive the Newton's laws of classical mechanics directly out of quantum theory. Moreover such an approach allows to explain the frequency steps of quantum standards and also irregular globally-correlated variations of frequency quantum standards.

OSCILLATOR VARIATIONS IN TIME AND SPATIAL DISPLACEMENT

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Measured period variations of atomic and piezoelectric oscillators are proportional to spatial and daily variations of gravitational characteristics, nonmagnetic body action on oscillator. Also measurements were undertaken on global scale in the regions of tectonic rifts at the Atlantic Ocean. There had permitted to discern both the topographical features of the Ocean floor as well as the fluctuations in density of these features thereby. At spatial oscillator circulation, it was found non-zero period variation and its relaxation time depending from next density objects that was matched up to different elastisity properties of them. Proposed theory model is based on represantation of specific gravity effect, i.e. deformational interaction with elastic constant of masses consisting of quantum mechanical statistical ensambles of interacting microparticls, including working substance of sensor (oscillator), with adiabatic changing their internal energy and oscillator line shift, interaction of said masses through gravity curvative - "some agent acting constantly according to certain laws" whereby "gravity must be caused." (Newton, Letters to Bentley). Gravity deformational rotatial component with gravity dynamical Newton component put together unified gravitational field, which is described by system of gravity elastic field equations and is established their connection with electromagnetic field equations according to possibility of inducing electric charge by definite value of gravity curvature. This phenomenon may be used for gravimetric independent from inherent extraneous accelaration measurements in different applications.

EIGENFREQUENCY VARIATIONS OF THE QUARTZ GENERATORS DURING THE TOTAL SOLAR ECLIPSE

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To confirm the concept that nonstability of the eigenfrequencies of the quartz autogenerators has a solar nature the experiments were carried out of the measuring this nonstability during the total solar eclipse observed in March 9, 1997 over the area of East Siberia in Russia. The measuring system was developed involved four identical quartz autogenerators. One of them is operating as an impulser and the others are operating as electronic counting period meters. These period meters measure the variations of the period of time mark passages with the accuracy 10^{12} forming the three channel measuring system. Each channel of this system has its own ability to "see" the Sun during the day. Well defined variations of the period of time mark passages were registered by one of the channels at certain phases of the eclipse. This is supposed to be associated with the peculiarities of the mutual spatial orientation of the crystallographic axes of the quartz resonators of this channels.

THE SUN AND THE NONSTABILITY OF THE EIGENFREQUENCIES OF THE QUARTZ AUTOGENERATORS

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It is known that the nonstability of the eigenfrequencies of the quartz autogenerators encluded in various radioelectronic equipment reveals the time variations over rather wide range. These variations exist in spite of the fact that quartz resonators of these autogenerators are thermostatted, vacuum treated and shielded from external electromagnetic fields. For the purpose of studying the characteristics of these variations the frequency deviation of one resonator is measured relative to the other with an accuracy of 10^{-11}. The time constant is $10^3 s$ and the experiment duration is 444 days. The characteristic features of these variations suggest their solar nature. The relative frequency variations have the diurnal periodicity with the amplitude determined by solar activity level. It confirms these variations to be affected by seasonal variation of the Sun's declination and the heliographic latitude of the solar disk centre. The variations have the component that reveals the association with solar activity phenomena and is 35 days ahead of them. It is likely to be caused by the processes at the bottom of the convective zone. The sidereal anisotropy is also found in the amplitude of the diurnal variation coincided in direction with the anisotropy of the space microwave background.

ON THE MAXWELL APPROACH TO GRAVITY

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Similarity of Coulomb and Newtonian gravity laws inspired a lot of scientists (and "fathers of electrodynamics" in their number) for attempts to describe gravity with the help of Maxwell equations. But all of them came to a conclusion that such "linear transfer" is invalid because it violates energy and impulse conservation laws. This paper proposed gravity field description with the help of Maxwell equations in which the first rank derivatives with respect to t is changed for the second rank ones. Such a description is coordinated to energy and impulse conservation laws, coincides with Newtonian gravity law in static case, predicts general relativity theory effects: planets perihelium shift, red gravitational removal and ray deviation in the sun field.

In addition it gives a uniform explanation of some facts which now are explained ad hoc or are not explained at all. They are: Phobos falling on Mars, the differential rotation of the Sun and gasoliquid planets, the proximity of natural satellites' orbits to equatorial plane of the central body, the Earth's continental drift, the observed type of atmosphere and ocean currents, the source of energy for Earth's magnetic field, etc. The physical and mathematical meaning of Bor's orbits of electrons in atoms, the dynamics of the solar systems development becomes more clear. One can surely assert that the field we now call nuclear is gravidynamical.

GEOPHYSICAL MANIFESTATION OF INTERACTION OF THE PROCESSES THROUGH THE ACTIVE PROPERTIES OF TIME

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The experiment on verification of existence of new type of physical interaction suggested by N.A.Kozyrev was performed. The experimental setup included two types of detectors measuring the self-potentials of the electrodes in marine water and the dark current of the photomultiplier. Both detectors were protected of known sources of classical effects. Natural time variation potentials and dark currents were recorded in period randge 1 minute - 1 year. Number of new effects was discovered: correlation of potentials with dark current and potential on another distant setup; advanced reaction of the potentials on the Earth magnetic field; nonlocal reaction of the potentials on environmental temperature with retarded, instantaneous and advanced lag; relation of potentials with sudden ionospheric disturbances. Interpretation of this effects on the base of developed Kozyrev's idea on the active properties of time is rather succesful.

ON THE FORCES BETWEEN TWO MOVING ELECTRIC CHARGES

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Electrodynamics are considered to be a beautiful specimen for other sections of physics. But two points in it look unsatisfactory:

1. electrodynamical forces do not satisfy the third Newtonian law,
2. some experiments produced by scientists in Russia, USA, Austria and other countries show existence of electrodynamical forces which are not described by modern electrodynamics.

Generalized formulas for Lorentz force and Maxwell equations are proposed. These formulas satisfy the third Newtonian law, predict classical forces for classical cases and some nonclassical forces (in their number all the forces appearing in experiments known to the author). They also predict appearing forces of the third rank smallness with respect to light velocity c which apparently are manifested in electro-weak interaction.

A FORCE PRODUCED ON STATIC ELECTRIC CHARGE BY CURRENT IN NEUTRAL CONDUCTOR

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This experiment is one of the experiments produced by scientists in different countries which show existance of nonclassical electrody - namical forces. It took place in St.-Petersburg State University and showed that current in neutral conductor produced force on static electric charge.This fact is not forcasted by modern electrodynamics. The report shows that appearing of such a force is forcasted by generalized Lorentz formula and generalized Maxwell equations pro - posed by the author.

SOME ANOMALIES ON THE EARTH IN THE TIME OF JOVIAN CATASTROPHE

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It was a fact well known that over 20 fragments of comet Shoemaker-Levy 9 would collide with Jupiter during the certain period of July 1994. Geocentric distance of that planet and the accuracy of the impact time data allowed us to realize an experiment, which was originally planned by way of the observations of a possible communication between some events on Earth and the events of that catastrophe on Jupiter. We suggest to compare two independent sets of data: the moments when we registered the beginning of the specific anomalies in the usual matter state dynamics of several different systems simultaneously and the moments of the corresponding accepted impact time. We used two different types of indicators for the estimation of speed of the expected communication and two different systems for the estimation of a system state change. Our observations demonstrated that the light signal was 43 minutes late than the indicators' reaction (fragments A, F, M, N, Q2, Q1) and the systems discovered the expected out-of-the-way action: their total state change was the unusually prolonged (till the 21th of October 1994 and till now, respectively) irreversible one. We consider these observations in the light of the possible communication through the temporal channel of space-time.

Forces originating ocean flows

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Earth magnetism,ocean and atmosphere flows,continental drieft become object of thorough investigation .
Now a day scientists accurately know energy and mass currents,velo cities of flows,ostilations of hundreds of parameters.One knows every thing except the reason why these processes are such and not the others,where the energy source for them is .
A mathematical model is proposed which explains these phenomena with gravimagnetic field similar to that in electromagnetic theory .
The picture of ocean currents is researched in detail.Good conformity betweentheory and observed ocean currents is shown.

PHYSICAL ANOMALIES CONNECTED WITH THE SUN

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In this paper we consider the results of scanning of the Sun's daily parallel in the neighbourhood of the solar disk (from 18^m ahead it to 16^m behind it along right ascension) with sensors of various nature (some metal-film resistor, *E. coli* cells, some minerals) by Kozyrev's method. These sensors have shown that there are two pronounced anomalies: at 8^m and 16^m (accurate up to 1^m) ahead of the solar disk. The anomaly corresponding to the apparent Sun is weak and irregular, and as a rule is not observed in the case of a sensor of biological nature. Experimental research has revealed that a live system experiences an intensive many-sided superactivating influence not from the apparent Sun, but from the region at 8^m ahead it. The size of that region along right ascension and along declination had corresponded to the solar one. Taking into account many specific properties of this physical phenomenon and also the physical meaning of the corresponding points on stars' daily parallels, from which the sensor experiences the corresponding influence when we study a star's daily parallel by Kozyrev's method, we discuss the meaning of Sun's daily parallel as Sun's world line *if we consider the terrain observer's celestial sphere as his World of events (space-time)*. We give the physical interpretation of these anomalies as an appearance of the physical reality of the terrain observer's World of events.

THE WAVE EQUATIONS FOR OSCILLATOR WITH PLANCK'S CONSTANT AND FORCE QUANTUM

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The model of oscillator with mass m in slowly rotating coordinate system is considered. The expression for potential energy of oscillator $U = mw^2x^2/2$ is symmetric with respect to angular frequency of rotation w and radius of rotation x. Provided that in case of small w not the mechanical angular momentum mwx^2 is quantisied, but force mw^2x, the wave equations of mass motion are examined. The spectrum of values of oscillator energies $E_n=Hx(n+1/2)$ is obtained, where H - has the meaning of a force quantum, $n = 0, 1, 2,..$. Theoretical estimate for H is $(10^{-36} - 10^{-37})\ N$. This estimate is obtained from an observational cosmology. The presented model has a methodical sense as it permits to derive the Newton's laws of classical mechanics directly out of quantum theory. Moreover such an approach allows to explain the frequency steps of quantum standards and also irregular globally-correlated variations of frequency quantum standards.

HISTOGRAM FORM RECOGNITION: ALGORITHMS AND SOFTWARE

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The macroscopic fluctuations investigations (S.E.Shnoll et al., Russian Chemical Journal, v.41, No.3, 30-36, 1997) include in its core the procedure of histogram forms comparison. The software for such a comparison based on expert evaluation of similarity was developed. It is very important to develop the algorithm of histogram forms comparison for automatic analysis of macroscopic fluctuations in time series. The approaches based on correlation analysis, neural nets and fuzzy logic are discussed in this work.

RELIABILITY OF THE "NEUTRINO-GRAVITY CORRELATION" EFFECT DURING OF THE SN1987A EXPLOSION: A STATISTICAL MIRACLE OR PHYSICAL REALITY?

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A neutrino-gravity correlation effect was reported in the series papers by the Roma-Torino-Meryland collaboration. The effect consists in fixation of a remarkable correlation between the unified noise background of the room temperature gravitational detectors in Roma and Maryland and a neutrino background registered by the Montblanc neutrino telescop as well as others (Kamiokande, MIB) during of the SN1987A explosion. An immediate interpretation of the effect as a result of the gravitational and neutrino fluxes from a collapsing star have met serious objections from the point of view a required energy of gravitational pulses. Several other investigations were carried out in attempts to clarify a nature of the effect considered as some global affectation. In that number a searching of a correlation with other elementary partical backgrounds. with seismic noise background etc. In this talk we propose a methodics of data analysis which was based on a general approach of the theory of optimal filtration. We apply this methodics to the real data collected by RTM group during of SN1987A and we find a correct estimation of reliability of the "correlation effect". We also give some argumentation in discussion of a possible nature of the effect.

SENSORS AND SOURCES OF SPONTANEOUS VARIATIONS (SV) OF PHYSICAL PARAMETERS

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Parameters, whose variations were observed, are: eigenfrequency of torsion pendulum, quartz and atomic time standards, resistivity of resistors, volume of mercury in thermometers, dark current of photomultipliers, velocity of phase transitions, chemical reactions, radioactive decay, relaxation time, electrophoretic mobility and so on. All this systems may be considered as sensors of SV. Futhermore we can suppose that any parameter varies at its inherent level and variations become observable when measurements are sufficiently sensitive and all the trivial influences are minimized. SV spectrum is near to 1/f and we may suppose that SV are a component of flicker-noise. The observed SV effects of solar activity and eclipses shows that the Sun is the strongest source of SV. Other sources are geodynamic, atmospheric, hydrologic, biospheric processes that open a new informational channel for their study and forecast.

PHENOMENON OF SPONTANEOUS GLOBALLY SYNCHRONIZED VARIATIONS OF PHYSICAL PARAMETERS (SV)

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The physical parameters of a system are dependent on external conditions: temperature, pressure, EM-radiation etc. If all the known conditions are stabilized we expect stability of the parameters. Nevertheless, the variations occur. They correlate for measurements in rather distant locations, correlate with solar activity and apparently with cosmic and terrestrial events. It means that SV are not truly spontaneous but ruther quasi-spontaneous, as they are induced by some external influence of unknown nature. What may it be? 1. Some difficulty controlled particles like neutrino, mu-mesons etc. 2. Hypothetic variations of space-time curvature or torsion. 3. Stream of negentropy. N.A.Kozyrev (1908-1983, 2 Sept 1998 is his 90 anniversary) gave evidence that if in a system entropy rises and organization decreases, the latter one does not disappear but eradiates and carries away as stream of negentropy ("stream of time" in Kozyrev's terminology), to be transferred to some other system(s) and give rise to organization growth which varies the parameters of objects therein.

RESULTS OF OBSERVATION OF EXTRAGALACTIC OBJECTS.

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Statistical calculation of extragalactic objects observations shows that
1. Objects'density flows are seems $S = S_1 + S_2$, where S1 is flux densities of synchrotron radiation, S2 is flux density of thermal radiation.
2. The first ones dominate in quasars, BL Lac objects and radiosources. S1 is inversaly proportional to distance r, observable number of objects N1 is proportional to r^2
3.the second ones dominate in galaxies groups and clusters of galaxes. S_2 is inversaly proportional to r^2, N_2 is proportional to r^3
4. The objects distances are proportional to ln (l + z), where z is redshift , i.e. Hublle's law is defined by photons'growing old and met by Universe expansion .
5.Angular diametrs of similar type objects are inversaly proportional to the distance.

ON THE DISCRETENESS OF DIFFERENT PROCESSES TIME SERIES MEASUREMENTS WHICH RESULTS FROM COSMOPHYSICAL SOURCES

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The biochemical and chemical kinetics , the electrophoretic mobility of cells and particles, water protons cross-relaxation time, neon lamp discharge time, earth core vibrations and the intensity of radioactive decay of different isotopes were measured by suitable methods. As a result of long-term measurements (during 1955-1997) of fluctuation distributions the existence of universal cosmophysical "force" wa proved. This force determines at each time moment the current spectrum of discrete characteristics of different nature processes (the form of appropriate histograms). Performing measurements at different locations (in Pushchino, Moscow, Leningrad, Tomsk, on the coast of White Sea, aboard in Pacific and Indian oceans) it was shown that the form of appropriate histograms changes there simultaneously. The "lifetime" and the periodicity of the given form appearance exist =96 in the series of subsequent histograms the given histogram is the most probably similar to the nearest neighbors and repeats after 24 hours, 27 days and about 365 days. The appropriate changes of histogram forms in time and their similarity in the measurements of different nature processes and at different geographical locations are the evidence of the existence of common cosmophysical (cosmogonic) source of the discussed phenomena.

STUDY OF THE TEMPORAL VARIATION OF THE GRAVITATIONAL CONSTANT

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The value of the gravitational constant is known with less accuracy than other fundamental constants of physics. Authors of the best G value determinations claim to their experimental results an accuracy of 10^{-4}. A simple comparison of the gravitational constant values obtained by different researchers shows however that the disagreement between the individual results is of the order of 10^{-3}. An other problem connected to the gravitational constant G is its temporal variation as supposed by many authors. This follows from Dirac's expanding Universe model proposed in 1937 what leads to decreasing constant of gravitation and to the geohysical theory of expanding earth. Our study based on the tidal friction history during the last 2.5 billion years with the use of the law of conservation of the angular momentum shows that during the half span of life of our planet $dG/dt \geq 0$ what is in contradiction with Dirac's theory as well as with the theory of the expanding Earth.

ON THE SIMILARITY OF HISTOGRAMS FINE STRUCTURE FOR SYNCHRONIZED TIME SERIES OF DIFFERENT NATURE PROCESSES AT DIFFERENT LOCATIONS

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The discrete distributions of measured values could be obtained for time series of different processes ("macroscopic fluctuations"). The fine structure of distributions (the shape of appropriate histograms) turns to be similar with high probability for different nature processes, sampled by appropriate methods at different locations. These conclusions result from histogram form comparison: - chemical reaction (Pushchino, 120 km from Moscow) vs BZ-reaction (Tomsk); - chemical reaction (Pushchino) vs tritium beta-activity (St.Petersburg); - plutonium alpha-activity (Moscow) vs carbonium beta-activity (Pushchino); - earth core vibrations (Tbilisi, Georgia) vs plutonium alpha activity (Pushchino); - plutonium alpha-activity in Pushchino vs aboard in Pacific and Indian oceans; - plutonium alpha-activity in Pushchino vs on the coast of White Sea; - carbonium beta-activity vs water proton cross-relaxation time (Moscow). In all cases histograms are similar with higher probability at the same absolute time moment. These results support the idea of global source of observed phenomenon.

ON THE SYNCHRONIZED CHANGES OF HISTOGRAMS FINE STRUCTURE FOR TIME SERIES OF RADIUM FAMILY ISOTOPES ACTIVITY

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The investigated in our laboratory effect of macroscopic fluctuations points to the existence of "global force" determining the fine structure of measurement values distribution at different processes (S.E.Shnoll et al., Russian Chemical Journal, v.41, No.3, 30-36, 1997). The radioactive decay is the most convenient way to investigate this "force" because of its low sensitivity to the environmental influences. In this work time series of activity of radium family isotopes equilibrated in the same sample were analyzed in detail. The simultaneous meauserements of different isotopes activity were made by one semiconductor detector and multichannel analyzer since the energy of radiation differs for different isotopes. It was shawn that the fine structure of measurements distribution for different isotopes is similar with higher probability when measurements are synhronized.

A NEW CLASS OF PHENOMENA IN NATURAL PROCESSES AND TECHNOLOGIES

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Results of experimental and theoretical studies of real different type interaction in various natural phenomena (phase transitions, photoeffect , chemical and nuclear reaction rates, ore building,processes in plants as well as bacterias etc.) are represented.Universal mathematical discription in a simple algebraic form of evolution of real systems with changing external conditions is obtained.Principles and laws of classical dynamics are sufficient to understand and to discribe systems reactions upon the field influences.

. Some erroneous notions and delulusions existing in modern physics and being connected with incorrect translation from Latin and interpretation of classical heritage are mentioned. A quantum dynamical approach for analyses of phenomena is represented. A solution for dynamical aspect of the multi-body problem is given .The mechanisms of selecting interaction ensuring processes of organization, selforganization and energy inversion in natural systems and technologies aredeveloped.The suggested approach allows to understandfrom a unified point of view a wide range of phenomena related to the "fifth force", may stimulate future research in physics,geophysics,astronomy etc.

OA17 Climate variability: models and observations (co-sponsored by SE) Overview session

Convener: Komen, G.J.

EUROPEAN AND ATLANTIC CLIMATE VARIABILITY

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Natural climate variability in the extratropics occurs on all time scales, from interannual to centennial, and beyond. These variations, typical for the variability of European climate, are influenced by the oceans. They affect mean conditions but also the occurrence of extremes. Understanding and - if possible - prediction of these variations is important, also for the detection of anthropogenic climate change.

It is recommended that Europe develop a major modelling and observation programme to improve understanding of the role of the Atlantic Ocean in climate. This requires improved observation and understanding of the modes of climate variability in the Atlantic region and an assessment of the degree to which these are predictable. The required concerted effort in ocean observation, improvement in atmospheric analyses and palaeo reconstructions, coordinated modelling and process studies will be outlined.

CLIMATE VARIABILITY DEDUCED FROM THE MODERN AND PALEOCLIMATIC RECORDS

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CLIVAR and EUROCLIVAR diagnostic studies will rely upon existing records of instrumental data and proxy-data derived from paleoclimatic indicators. As the instrumental record is short and documents only a few examples of climatic events with interdecadal time scales, diagnostic studies of climate variability will rely, in a fundamental way, upon paleoclimatic proxy-data. The seasonal to centennial variability of the climate system can be deduced by annually-laminated sediments, corals which grow at rates of millimeters per year and produce annual growth bands, tree rings which develop in areas of large seasonality, and ice records of $\delta^{18}O$, δD and conductivity. The decadal to centennial variability of the climate system is recorded in polar and tropical ice cores, in loess sediments and in specific areas of the world ocean characterized by extremely high accumulation rates. A strategy was established by the EUROCLIVAR scientific committee to make the best use of available data, to generate additional data from meteorological observations (both in the atmosphere and the ocean) and proxy-data, and to assimilate these data in climate models.

SCALE INTERACTIONS AND GLOBAL TELECONNECTION PATTERNS.

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The climate in a region can be considered to be the ensemble of the weather systems that affect that region. The behaviour of these weather systems may be modulated on a range of timescales often associated with the lower frequency variability of the oceans. In turn, these weather systems themselves may influence that low frequency variability. In the tropics there is increasing evidence that scale interactions involving atmospheric intraseasonal variability, particularly associated with the Madden-Julian Oscillation and Westerly Wind Bursts, may affect the development of El Niño. The impact of El Niño on the climate is profound due to teleconnection patterns which extend over the entire globe. These teleconnections are recognized as major modes of climate variability.

During the early months of 1997 the tropical Pacific Ocean underwent a dramatic transition from La Niña conditions in December 1996 to a major El Niño by June 1997. The evolution of this event and its impact on global weather will be used to illustrate the importance of scale interactions and global teleconnections as future priorities for research within Europe.

CLIMATE CHANGE PREDICTION AND DETECTION USING COUPLED CLIMATE MODELS WITHIN EUROPE

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Anthropogenic climate change studies within Europe using comprehensive coupled climate models have made significant advances in recent years. Recent improvements in models, advances in modelling studies, and some outstanding modelling issues are discussed, illustrated with recent results from Hadley Centre and other European models. Established modelling centres (eg. UK Hadley Centre, DKRZ Hamburg) have built on experience from earlier coupled models to develop new models with higher resolution, better simulations of present-day observed climate, and allowing improved representation of anthropogenic forcings. At the same time, natural and anthropogenic climate forcing factors other than just greenhouse gases (eg. anthropogenic sulphate aerosols, variations in solar output, and past volcanic eruptions) are increasingly recognised as important to include in climate change detection and attribution studies. Uncertainties inherent in the chain between assumptions about anthropogenic emissions and corresponding conclusions from climate models about global and regional climate changes mean that present diversity in modelling approaches is healthy, model intercomparison studies adding value to conclusions from any single model. Improving representations of clouds and eliminating artificial flux adjustments are two related focuses for model improvement. Model predictions are vital tools for the detection and attribution of climate change. Findings from a recent Euroclivar workshop on this topic will be summarised.

CLIMATE MODELS: CURRENT UNCERTAINTIES AND FUTURE PROSPECTS

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Numerical Models constitute an essential tool of our discipline, necessary both to understand the complexity of the natural fluctuations of climate and to predict its future evolutions, at any time scale. Their performance , resolution, complexity has been steadily increasing over the last decades. Most centers now run coupled ocean/atmosphere models, and the inclusion of chemical or biochemical models in both th ocean or the atmosphere is in progress. Yet the basic uncertainty attached to future climate predictions (in response to the anthropogenic greenhouse effect for example) has not been diminished. By many respects the results of models designed independently is our only measure of this uncertainty. At the same time the large number of models may be felt as some uncessary waste of energy by the scientific community if it is not used in some consistent way. The presentation will review some of the intrisic difficulties with which modellers are being faced and will take the example of cloud feedbacks to illustrate the possible benefits of common model intercomparison or model validation exercices. The main conclusions of the Euroclivar panel concerning model studies will then be reviewed and opened to discussion.

OA17 Climate variability: models and observations (co-sponsored by SE)

01 West African monsoon studies

Convener: Thorncroft, C.D.

Rain event climatology in West Africa : Comparison from in situ and GCM outputs

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West Africa has suffered from a continuous drought for the past 30 years. In order to assess the impacts of this drought onto the processes conditioning the continental water cycle, the rainfall variability has to be studied at smaller scales than the usual monthly and yearly scales. Recent works based on in situ observations suggest that, in the Sahel, there is a dominant co-fluctuation between the number of rainy events and the cumulative rainfall at various time scales (see Lebel et al., this session). This has strong implications for the hydrological cycle and it is therefore important to verify whether this feature is reproduced in GCM's used to evaluate the impacts of climate fluctuations onto the water resources in West Africa. A first step in that direction has been taken by investigating how the GCM rain event characteristics vary when averaged over two contrasting periods : the wet years 1951-1970 and the dry years 1971-1990. The fluctuations observed in the GCM outputs are compared to those recorded over the same 2 periods by the regional network covering a 12°(latitude) x 15° (longitude) window. The two parameters considered here are the number of events and the mean event rainfall. It is found that the number of events produced by the GCM has decreased significantly during the dry years, as compared to what it was during the wet years. In that respect, the GCM conforms to the observations. On the other hand, the average characteristics of the GCM rain events are somewhat different from those of the observed rain events. The various reasons, mainly the sampling characteristics and the GCM parametrisation, that may explain these differences are discussed.

BLOCKING SIMULATION IN GENERAL CIRCULATION MODELS WITH DIFFERENT RESOLUTIONS

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Different outputs of three general circulation models (CNRM ARPEGE, UKMO and MPI ECHAM4), integrations at different resolutions (up to T106 equivalents triangular truncation) but with the same sea surface temperature, have been analysed from the point of view of blocking simulation. The analysis has been developed with the help of an objective blocking index based on the quantification of the zonality of the flux. For each model integrations, systematic errors and model variability have been assessed. In general all the model runs tend to underestimate blocking frequencies especially in the Pacific, where blocking appears more dependent on the oceanic forcing rather than on the internal dynamics of the atmosphere, but their behaviours as the resolution increases is very different. ARPEGE model is characterised by a strong tendency to decrease the already too low blocking frequency even if the position of maxima of variability (both low and high frequency) is better reproduced in the high resolution run. On the contrary ECHAM4 model shows an improving, as the resolution increases, both in space and in time simulations but only on the Euro-Atlantic sector. In particular the model reproduces realistically the interannual variability of this sector. The UKMO model has been found to be rather insensitive to model resolution variations .Additionally, it is the only model which overestimates somehow the frequency in the Euro-Atlantic sector at all resolutions. The yearly cycle is improved by increasing resolution but not the same can be said for the interannual variability.

DIFFERENT REGIMES OF EASTERLY WAVES OVER WEST AFRICA AND TROPICAL ATLANTIC (1979-1995)

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NCEP/NCAR reanalyses are used over the period 1979-1995 to investigate the easterly waves activity over West Africa and the tropical Atlantic and its relationships with rainfall and convection. Three main band-periods are pointed out in spectral analyses of meridional wind at 700 hPa : 3-4 days, 4-5 days and 6-9 days. The 3-4-day and the 4-5-day regimes correspond to the well known easterly waves activity respectively south and north of the African Easterly Jet. The 6-9-day regime corresponds to similar easterly waves north of the jet but with stronger associated anticyclonic circulations behind the wave trough. The modulation of rainfall and convection by these two wave regimes is investigated by using ORSTOM and NCEP/NCAR daily rainfall amounts and three hourly ISCCP satellite data. Energetic computations are also performed to discriminate the two wave regimes.

LARGE-SCALE DYNAMICS AND THE WEST AFRICAN MONSOON

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The West African monsoon is discussed from the perspective of the large-scale atmospheric hydrodynamics. Studies with a general circulation model and diagnosis of NCEP and ECMWF reanalysis products are used to understand how and why the low-level monsoon flow and the African easterly jet are forced, and to investigate their role in determining the precipitation climatology. Moisture transport and convergence within the monsoon flow is examined through a consideration of the moisture budget. The vorticity budget is used to explain how the flow across the Guinean coastline balances vortex stretching due to mid-tropospheric condensational heating, thereby maintaining the precipitation. The African easterly jet, which is the result of strong surface heating at Saharan latitudes, contributes to the total vertically-integrated moisture budget over West Africa through its association with a moisture divergence maximum near 700 mb. This connection results in added sensitivity of the West African climate to land and sea surface temperatures, since the jet is sensitive to the large-scale meridional temperature gradient. The large-scale dynamics of West Africa is compared with that of East Africa to suggest reasons for the observed similarities and differences in precipitation variability.

Numerical study of interactions between a squall-line and an easterly wave

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The relationship between convection and easterly waves is one of the key factors for understanding the west African monsoon. Up to now these interactions has been mainly studied owing to composite analysis of observations (Reed et al 1977) and to idealized modelling studies (Simmons 1977). On the other hand explicit resolution of convective systems such as squall lines, was restricted to limited domains of simulation without any realistic treatment of the initiation stage and of forcings by larger scales. Recent progresses in modelling and computers allow us now to treat these scale interactions more explicitely for some case studies.

Here the atmospheric simulation system Méso-NH is used to simulate a squall line associated with an easterly wave and observed on the 22 august 1992 during HAPEX-SAHEL in Niger. Two types of simulations are performed. First meso-β ones (30 km resolution) initialized by the ECMWF analysis and fine scale surface conditions, to represent the dynamics of the easterly wave owing to the use of a convective scheme. These simulations are then used to forced and initialize the squall line explicitely resolved (2 km) by a second model nested in the first one. We will present the validation of this approach on the base of comparisons with available observations (satellite and radar imagery, precipitation and convection footprints as observed by HAPEX-SAHEL ground stations)

SIMULATION AND PREDICTION OF THE WEST AFRICAN MONSOON

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One objective of the European Union PROVOST experiment is to estimate potential dynamical seasonal predictability given ideal surface boundary conditions on a global scale. To this end, the UK Met Office Unified Model (at climate resolution) has been integrated in 9 member ensembles initialized at 24-hour intervals over 15 Boreal summer seasons (June to September) from 1979 to 1993. Initial conditions from the ECMWF reanalysis as well as SST anomalies from the UKMO GISST and Reynold's OI data sets were used in all the experiments.
Tropical West Africa is one region chosen in order to test the capability of providing seasonal forecasts. Probabilistic and deterministic rainfall predictability appear to exist over this region in the PROVOST simulations. The dynamical model is able to capture the interannual rainfall variability reasonably well but underestimates magnitudes. Since 1994, dynamical forecasts have been produced at UKMO for tropical west Africa, the difference from the PROVOST runs is that persisted SST anomalies from May are used throughout. It appears likely that there is minimal loss in predictability through the use of persisted anomalies if the results from 12 boreal winter and spring experiments can be extrapolated to summer. Assessments of the 1997 monsoon forecast will be presented in both probabilistic and deterministic terms.

INTERANNUAL VARIABILITY OF INTRASEASONAL AND SYNOPTIC WEATHER SYSTEMS OVER WEST AFRICA ON THE PERIOD 1968-1997

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During the drough Sahel period beginning in 1968, the impact of ENSO events on Sahel rainfall has seemed stronger than before. NCEP/NCAR reanalyses are used over the period 1968-1997 to investigate interannual variability of synoptic weather systems like easterly waves as well as intraseasonal scale weather systems like monsoon surges and their impact on rainfall events. We investigate also the possible teleconnections with ENSO variability, especially linked to the heat source in the eastern equatorial Pacific.

VARIABILITY OF THE WEST AFRICAN MONSOON ON INTRASEASONAL AND INTERANNUAL TIME SCALES

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Using 22 years (1974-1996) of twice daily outgoing longwave radiation (OLR) observations and 15 years of ECWMF reanalysis data (1979-1993), the intraseasonal (June-September) and interannual variability of certain components of the West African monsoon (WAM) will be investigated. The focus will be on the intraseasonal and year-to-year variations in the African Easterly Jet and in the associated activity and climatological track of African Easterly Waves (AEWs). The activity and the mean track of AEWs are estimated by local variances of 2.5-8 day bandpass-filtered time series of both kinematic and thermodynamic/moisture variables (e.g., relative vorticity and meridional wind at 700 hPa, OLR and precipitable water). Differences in the obtained AEW statistics as inferred from both types of variables are discussed. Their relation to variations in moisture advection by the low-level southwesterly monsoonal flow and to the rainfall performance of the WAM is shown.

Rainfall variability in the Sahel : a matter of scales

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Rainfall variability in the Sahel has become notorious due to the lasting drought that started in the end of the sixties. This is the manifestation of a decadal variability mode which has been analysed by various authors using monthly and yearly averages. By averaging over such large time steps, the high frequency modes are lost, although they are of key importance for the hydrologic cycle. Using a combination of high resolution data collected during the 7 years of the EPSAT-Niger experiment and lower resolution data produced by regional networks over longer periods (typically 40 years), it is shown here that the Sahelian rainfall variability displays some common features at different scales ranging from intraseasonal to decadal. The fluctuations of the number of events explain 80% of the fluctuations of the average rainfall at both the decadal and interannual scales. At the intraseasonal scale, the rainfall maximum observed during the core of the rainy season is associated to both an increase in the number of events and an increase of the rainfall efficiency of the large Mesoscale Convective Complexes (MCC's). Tracing the atmospheric circulation patterns that might be linked to the fluctuation of the number of events thus appears as being a major challenge for the West African Monsoon Project (WAMP).

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CLIMATE IMPACT OF AIRCRAFT EMISSIONS IN THE UPPER TROPOSHERE. STUDIES WITH A 2D-MODEL

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The climate impact of aircraft emissions was studied with an interactive dynamical-chemical radiative 2D-model based on a standard climate 3D-GCM (ECHAM) and a coupled NCAR chemistry module. The main feature of the 2D-model is a selfconsistent parameterization of the tropospheric eddy heat and momentum fluxes. Sensitivity studies with and without zonally averaged aircraft NO_x emissions will be presented giving a better understanding of the dynamical-chemical interactions and the climatic features of both the background and the disturbed atmosphere. For example, the results show the dependence of the NO_x background concentrations on the composition of downward sinking lower stratospheric air masses and on the tropopause structure in northern winter midlatitudes in the height of the main aircraft emissions injection area.

AUTOMATIC TRACKING OF WEST AFRICAN CLOUD CLUSTERS

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With the objective of building climatological statistics on propagation of African cloud clusters, and studying their morphological and radiative properties, an automatic method for tracking cloud clusters has been developed. Using Meteosat infrared full resolution images, the method allows for tracking systems of size greater than 5000 km2. A cloud cluster was defined as adjacent pixels colder than a brightness temperature threshold. We have chosen several thresholds such as: 213 K, 233 K, 253 K. The method is based on the cluster overlap between two successive images. The algorithm takes into account splitting and merging of clouds, and allows for an objective determination of parameters such as: size, mean temperature, temperature variance, duration, coordinates of the centre of gravity, speed, trajectory, eccentricity etc. In order to use the full space resolution, the study is limited to West Africa from the equator to 20°N latitude and from 25°W to 20°E longitude.
We found some artefacts we have to take into account in the utilisation of the algorithm outputs (border effects, effects derived from the quality of the available Meteosat data set, reliability of parameters in case of split or merging of clouds...). However the processing of several years of data shows that the algorithm is reliable and produces results suitable for the study of convective cloud systems. This has been done over 1993 to 1997. Trajectory, diurnal variation, location of initiation and dissipation, variation of parameters during the cloud life cycle are analyzed. ECMWF analysis are also used to comment the results obtained with the tracking.

PROPAGATION OF THE MESOSCALE STORM FLOW OF WEST AFRICAN SQUALL LINES

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Recent work has shown how the mesoscale flow in the vicinity of a squall line is forced principally by a gravity wave response to the line of convective heating. The vertical profile of temperature and 3D wind in the inflow to a system, which is known to be crucial to its maintenance, is modified to first order by this mesoscale flow. Application of these concepts to the West African region, where squall lines may be propagating at all levels, is particularly interesting, as the wavelike response may evolve upstream of the cloudy region, to precondition the inflow to the storm as well as the anvil region.

As a preliminary step to understanding the propagation of the storm flow upstream of a Sahelian squall line, the nature of the fast linear waves on the African Easterly Jet is described. The structure and dispersion relations for different modes have been computed by numerical solution of a modified Taylor-Goldstein equation. However, it is only through consideration of the forced solutions that the upstream impact of a squall line can be evaluated fully. The impact of upstream modification on the thermodynamic properties of the squall line inflow is discussed, and the implications of inflow modification on overall squall line evolution are considered.

INTERANNUAL VARIABILITY OF SST - TROPICAL CIRCULATION RELATIONSHIP ON THE PERIOD 1968-1997: FOCUS ON WEST AFRICA.

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The NCEP/NCAR reanalyses are used over the period 1968-1997 to investigate the impact of the main modes of SST variability on the monthly mean tropical circulation. In particular we examine the role of ENSO events in the interannual variability of the seasonal rainfallamounts of the West African monsoon. We will look at the different atmospheric responses in surface (SLP, trade and monsoon winds,..) and in the upper levels (velocity potentials,...), and compare these results with previous studies having used less sophisticated observations and modelling experiments.

ON THE EXISTENCE OF WARM CORE AFRICAN EASTERLY WAVES

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The existence of warm core African Easterly Waves (AEWs) north of the African Easterly Jet (AEJ) core has been clarified using radiosonde data and the UKMO global model analysis from the summer and autumn of 1995. Spectral analysis of wind data at Dakar (14.7°N, 17.5°W) and Bamako (12.5°N, 8.0°W) confirms the existence of waves with AEW period (2.5-6 days). At Bamako the AEWs were characterised by maximum amplitudes at the level of the AEJ whereas at Dakar the waves were characterised by maxima at low-levels. Strong low-level AEW amplitudes on the northern flank of the AEJ were also seen in the UKMO analyses. These low-level amplitudes extended over the ocean but displaced south of the land maximum. The low-level amplitudes arise in association with baroclinic interactions between the negative meridional potential vorticity (PV) gradient in the jet core and the positive low-level gradients of potential temperature, θ, enhanced by the presence of low static stability air north of the AEJ. The warm core waves follow the θ gradients over north Africa in contrast to the 700mb waves that follow the PV gradients that exist at the level of the AEJ. Lag correlation analysis shows that there is strong coherence between the warm core AEWs and the well-known cold core AEWs that propagate south of the jet.

CHARACTERIZATION OF SAHELIAN RAINFALL SPATIAL VARIABILITY AT A SCALE BETWEEN 1 AND 10 KILOMETRES : THE ARCOL EXPERIMENT (REGION OF NIAMEY, NIGER)

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Since 1988, the EPSAT-Niger experiment (Estimation des Précipitations par SATellite au Niger) has been carried out in a semiarid area near Niamey (Niger) to improve the understanding of the precipitation systems of Sudano-Sahelian Africa and to develop operational rainfall estimation algorithms for this region. This experiment is based mainly on the survey of a very dense raingauge network (30 to 110 raingauges) laid on a regular grid covering an area of 16 000 km^2. The first results pointed out different parameters which govern the quality and the climatology of the rainy season. Among those,the link between the number of mesoscale convective systems which represent the biggest part of annual rainfall and the total seasonal rainfall. To have a new understanding of these mesoscale systems, in 1993, a new raingauge network covering an area of 600 km^2, based on 6 parallel lines of about 70 raingauges (ARCOL Experiment - A la Recherche des Cellules Orageuses des Lignes de grain) was set up. Theses lines are oriented more or less North-South and are perpendicular to the main direction of circulation of these convective systems. For each line, the distance between the raingauges is about 1 kilometre. This particular network allowed to study the sahelian rainfall spatial variability at a scale between 1 and 10 kilometres and furthermore, it improved the knowledge of the internal mechanisms of squall lines (particular mesoscale convective system with a structure of the convective front very well defined, oriented North-South, and a preferential path East-West with a speed of about 50 km/h). For this last part, the network allowed to show the size of the basic convective cells (about 1-2 kilometres) which are very intensive, and allowed to follow their displacement.

DECADAL SAHELIAN RAINFALL ESTIMATION OVER AN AREA OF 1 DEGREE SQUARE : CHARACTERIZATION OF THE 'GROUND TRUTH' ACCORDING TO THE RAINGAUGE NETWORK DENSITY.

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The duration of the rainy season in the sahelian zone is about 5 months (may to september). The precipitations resulting from the monsoon flux which moves toward the north at this period are mainly composed of convective systems. These rainfall show a high spatial variability. The regional raingauge network in the Sahel is very sparse (1 to 5 raingauges over 10 000 km^2) hence the mean rainfall estimation over a specific surface is very difficult. Other methodologies to estimate the rainfall over areas are used like infra-red measurement from geostationnary satellite which have a good resolution in time and space, but at the present time the estimation algorithms do not show a good agreement with the measured rainfall on the ground in the Sahel. In addition the spatial variability of rainfall and the weak density of raingauge network do not allow a good validation of the satellite data because there is not a good 'ground truth'. However, in the region of Sahel, a good spatial estimation of rainfall would be necessary to follow the crops and to prevent possible starvation. In that case, a rainfall estimation at a regional scale (degree square) and at a time scale of ten days could be enough. The EPSAT-Niger Experiment (Estimation des Précipitations par SATellite au Niger), localized in the region of Niamey is based on the survey of a very dense raingauge network which presents a regular grid over an area of 16 000 km^2. Six years (1991-1996) have been studied where there is deficit and excess rainy season. The aim of this study is also to determinate the 'ground truth' over an area of 1 degree square (about 12 000 km^2) at a time scale of ten days and to propose abacus of rainfall error estimation according to the number of raingauges.

INFLUENCE OF SST ON OBSERVED MIDLATITUDE BLOCKING VARIABILITY

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In the context of the analysis of atmosphere low frequency variability and its modelling (particularly of blocking simulation produced in GCMs), a good performance of the model ECHAM4 T106 (10 years integration) has been found, mainly in the Euro-Atlantic sector . This integration, characterised by observed sea surface temperatures as the only external forcing, reproduces a blocking frequency time variability which matches surprisingly well the real one (reanalysis from 1 January 1979 up to 31 December 1988). In order to understand if these similarities are the product of chance or not, a Montecarlo simulation has been developed using a set of 1000 "alternative analyses" randomly generated from the real blocking frequency dataset (analysis from 1 March 1974 up to 28 February 1994, limited to 90°W-90E area). Observing the distribution of the correlation coefficients (calculated between each of the random maps and the model output), it has been found that the model output is correlated with the observed data with a value located 1.5 standard deviations right of the mean.

MAINTENANCE OF THE AFRICAN EASTERLY JET

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The maintenance of the African easterly jet (AEJ) has been examined using a zonally symmetric GCM with simple parametrizations. It is shown that the AEJ is maintained in association with two diabatically forced meridional circulations; one associated with surface fluxes and dry convection in the Saharan heat low region and one associated with deep moist convection in the ITCZ region equatorward of this. The heat low heating, which reaches the height of the AEJ around 700mb, is particularly important in maintaining the AEJ and its associated meridional gradients in potential vorticity. It is concluded that the mean observed AEJ results from a combination of the diabatically forced meridional circulations which maintain it and easterly waves which weaken it.

ROLES OF CUMULUS CONVECTION IN THE ATLANTIC EASTERLY WAVES

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Easterly waves are westward traveling tropospheric disturbances in the Tropics. They arise through a mixed barotropic/baroclinic instability of the low-level easterly jet. The importance of diabatic processes in the wave dynamics and energetics has yet been fully understood, due to poor representations of moist processes. A wave-CISK parameterization is often used in theoretical studies. To improve the representation of cumulus convection, one must first understand the role of mesoscale processes in the mass, heat and moisture budgets of the easterly waves, in addition to that of convective-scale processes. The main purpose of this study is to investigate these budgets and individual budget components for every phase of a composite easterly wave.

In this study, the UCLA/CSU cloud ensemble model (CEM) is used to explicitly simulate the macroscopic behavior of cumulus convection and its mesoscale organization during Phase III of the Global Atmospheric Research Program's (GARP's) Atlantic Tropical Experiment (GATE). Observed large-scale vertical motion and horizontal advections of temperature and moisture are used to drive the CEM for the entire Phase III. The simulations have been presented in Xu and Randall (1996). The observed easterly waves during Phase III were characterized as fully mature and strongly nonlinear. Only a composite easterly wave is studied with the simulated data. Compositing of data is accomplished by assigning each 3-hourly averaged variable to one of eight wave categories as in observational studies. Partitioning of convective and mesoscale stratiform regions is based upon the strength of updrafts/downdrafts (Xu 1995).

Implications for cumulus parameterization will also be discussed, based upon the results presented in this study.

NUMERICAL STUDY OF THE IMPACT OF ENSO AND DECADAL SCALE SST VARIABILITY ON SAHEL RAINFALL

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Sahelian rainfall is strongly dependent on surface conditions and SST play a key role at interannual time-scales. However ENSO phenomenon is seldom put forward to explain rainfall variability in the Sahel. As a matter of fact the statistical relationship is weak but mainly due to its unstability through time and seems to depend on the global SST context - a decadal or longer time-scale variability. Numerical experiments performed with an AGCM help to investigate changes in the relationship between ENSO related conditions and Sahelian rainfall relatively to the prevailing global context. Recent ENSO events occuring in warmer southern ocean context have clear impact on the Sahelian rainfall in consistency with observations.

Mechanisms of West African monsoon and land surface process interaction

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West Africa is an ecologically fragile area, with a low and extremely variable rainfall. A biosphere model, SSiB, was coupled with the COLA GCM to investigate the impact and mechanisms of land surface processes on seasonal and decadal variations of Sahal rainfall. The model was integrated for four years with and without vegetation cover degradation over the Sahel region. It has been found that the West African monsoon and African easterly jet are both sensitive to land surface processes. Changes in the annual cycle of Sahel rainfall in the degradation cases are consistent with observed climate anomalies of the past forty years. The condition of the land surface in West Africa has the largest impact compared with other sub-areas in the Sahel region. The monsoon flow from the Atlantic Ocean, then the moisture flux convergence, became weaker in the degradation cases. In contrast to the conventional hypothesis about albedo effects, it has been found that variations in the convective heating rate, which are caused by changes in latent-heat flux from the land surface and moisture flux convergence in the atmosphere, are the dominating factors in this process. Radiative cooling is a secondary effect. A preliminary study was also conducted to compare the effects of the land and SSTs.

OA17 Climate variability: models and observations (co-sponsored by SE)

02 Natural climate variability on the basis of past observations

Convener: Duplessy, J.-C.

GMSLP3: A GLOBAL MEAN SEA LEVEL PRESSURE DATASET.

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A global, observed, monthly, historical MSL pressure dataset (GMSLP3) has been developed to facilitate the validation of climate model results and the interpretation of observed global and regional climate variations. The dataset is composed of gridded values on a 5° resolution, dating back to 1871.

GMSLP3 is based on monthly mean land station data together with gridded ships measurements, which were subjected to a rigorous quality-control. These data, combined with data extracted from the National Centers for Environmental Prediction Reanalysis, were used to 'reconstruct' monthly gridded fields of MSL pressure using the 'Reduced Space Optimum Interpolation' technique developed by Alexey Kaplan of Lamont-Doherty Earth Observatory, Columbia University.

I will present an overview of the creation of GMSLP3, together with a brief discussion of its main features and improvements over previous versions of the dataset. I will also describe possible future avenues for development, including the creation of regional datasets for areas, such as Europe, where there are sufficient numbers of high quality observed data.

CHANGES IN BAROCLINICITY AND SYNOPTIC ACTIVITY ON THE NORTHERN HEMISPHERE FROM THE 1960s TO THE PRESENT AS SEEN BY DISTINCT DATA SETS

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The large number of deep cyclones over the North Atlantic / European area during the first years of the 1990s led to the supposition, that the meridional temperature gradient of the troposphere has strengthened within the preceding decades. In this study northern hemispheric tropospheric temperatures and synoptic activity - in terms of baroclinicity and the interdiurnal variability of geopotential heights - are examined. It is found that the lower tropospheric temperature gradients as well as the synoptic activity increased during that period over the cyclogenetic centres over Newfoundland and over the Northwest Pacific, leading to an enforcing of meridional heat exchange processes due to synoptic eddies. But over continental areas (Asia/Siberia) the tropospheric warming within the midlatitudes caused a decrease of the meridional temperature contrast between lower latitudes and polar regions. This result can be obtained from three largely independent data sets: namely analysis data of the German Weather Service (DWD), the *Comprehensive Ocean-Atmospheric Data Set* (COADS) and the NCEP/NCAR Reanalysis data. The close connection between monthly mean baroclinicity - in terms of Bjerknes' solenoidal term - and the synoptic activity, obtained from daily observations, is another instructive result of the study.

A GCM SIMULATION OF THE ^{14}C DISTRIBUTION IN THE GLACIAL OCEAN

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Natural radiocarbon (^{14}C) concentration is often used to assess the ventilation rate of the deep-water masses. At the Last Glacial Maximum (LGM), the ^{14}C concentration measured in sediments supports the idea of a different World Ocean circulation compared to present day, but due to the measurement uncertainties and the scarceness of reliable ^{14}C data, until now, a comprehensive ventilation sketch cannot be drawn. Here we investigate this question with a 3-D global OGCM that includes a radioactive decaying ^{14}C tracer, with a wind speed and sea-ice cover dependent surface exchange coefficient, but ignoring the complex biological carbon cycle. Two experiments under restoring boundary conditions are conducted, a reference run with present day forcing and a LGM simulation using CLIMAP SST and *Duplessy et al.* (1991) SSS reconstructions. The ^{14}C equilibrium distributions from the two experiments are presented. The modern ^{14}C is in good agreement with observations and offers a model validation as well as a reference state. The LGM ^{14}C distribution is compared with the few available reconstructions. The comparison with the modern simulation provides a clear view of the circulation changes, changes that are consistent with those inferred from proxies.

RAPID CLIMATIC EVENTS AND ASIAN MONSOON INTENSITY: MAGNETIC AND GEOCHEMICAL RESULTS FROM THE BAY OF BENGAL AND THE ANDAMAN SEA

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Results from high resolution study of magnetic mineralogy combined with major element geochemistry analysis, oxygen isotopes and ^{14}C AMS stratigraphy are reported for cores MD77-169 and MD77-180 located in the Andaman Sea and the Bay of Bengal respectively. In both cores the main magnetic mineral is PSD titanomagnetite with slight variations in grain size following orbital periodicities at 23 kyr and 100 kyr. The 23 kyr periodicity indicates that the variations of magnetic grain sizes are strongly influenced by the monsoon with relatively fine magnetic grains during periods of strong summer monsoon.
In core MD77-180, located at the mouth of the Ganges river, short term variations in magnetic grain sizes and in the chemical index alteration (CIA) are coeval during the last glacial period with the rapid variations observed in the $\delta^{18}O$ record of GISP2 ice core. The interstadials are characterized by fine magnetic grains and high CIA values. On the contrary, the cold Heinrich events correspond in core MD77-180 to intervals of relatively coarse grains and low CIA illustrating a decrease of the intensity of chemical weathering related to significantly drier conditions on the continent. We suggest that rapid cold events in North Atlantic during the last glacial stages are related to a weaker summer monsoon rainfall over the Himalaya via atmospheric teleconnection.

WINTER PRECIPITATION IN PORTUGAL: TRENDS AND VARIABILITY USING A LINEAR MODEL BASED ON WEATHER TYPES

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Regime of precipitation in Portugal presents a highly seasonal character, with a broad winter peak and an almost complete lack of rain in summer. Based on an objective classification of Weather Types (WT's) developed for the UK (Jenkinson and Collison, 1972) and adapted for the present purpose, daily values of SLP were used to define 10 different WT's according to vorticity and prevailing direction of geostrophic wind flow. In a previous work, statistically significant relationships were found between monthly values of precipitation and monthly frequencies (number of days) of relevant WT's, *i.e.* Cyclonic (C), Southwestern (SW) and Western (W) types. In the present work monthly frequencies of these three relevant CWT's covering the winter period 1946-90 were used to predict monthly mean values of precipitation at 18 stations over Portugal. Multiple regression models were therefore developed for each station using three most relevant WT's as predictors. Each model was calibrated using winter months and then validated against March observations, all models revealed a good capacity in reproducing the temporal variability of March precipitation, especially the conspicuous decline that has been observed since the 60's. Although the models present similar values of explained variance over the country (≈80%), relative importance of each WT is distinct from station to station, a strong decrease (increase) being observed in importance of C (W) type from South to the North. Obtained results put into evidence the different mechanisms of precipitation in Portugal, orographic and cyclogenic activity being relevant respectively in the North and South of Portugal.

PLIOCENE WARMTH IN MEDITERRANEAN AREAS: RECONSTRUCTION FROM POLLEN DATA

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The Pliocene was the last time where there is good evidence that climate was significantly warmer than the present time. So, it is important to quantify this last warming-up. Climatic reconstructions from Pliocene pollen data cannot be based on modern analogue methods, as Pliocene pollen spectra contain mixture of taxa that do not grow together today. A new method that uses a climatic amplitude method has been carried out especially for the Pliocene. It relies on climatic ranges tolerated by plants. The climatic requirements of the main taxa represented in the pollen spectra have been defined on the basis of 8000 modern pollen spectra. The method have been applied to several Pliocene pollen sequences of the Mediterranean area. Both temperatures and precipitations were higher than the modern ones, especially at the northern latitudes. Our results are comparable with sea surface temperatures and with $\delta^{18}O$ variations obtained for the same period.

FLUCTUATIONS IN NORTH ATLANTIC HURRICANE FREQUENCY

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The annual record of hurricane activity in the North Atlantic from 1886–1996 is examined using time-series analysis. Singular spectrum analysis (SSA) combined with the maximum entropy method (MEM) is applied to the time-series of annual hurricane occurrences to extract the dominant modes of oscillation. The annual frequency of hurricanes is modulated on the biennial, semi-decadal, and near-decadal time scales. The biennial and semi-decadal oscillations correspond to two well-known physical forcings in the local and global climate. These are the shift in tropical stratospheric winds between an east and west phase (QBO), and a shift in equatorial Pacific Ocean temperatures between a warm and cold phase (ENSO). These climate signals have previously been implicated in modulating Atlantic hurricane activity on the inter-annual time scale. The near-decadal oscillation is a new finding. Separate analyses on tropical-only (TO) and baroclinically-enhanced (BE) hurricane frequencies show that the two components are largely complementary with respect to their frequency spectra. The spectrum of TO hurricanes is dominated by the timescales associated with ENSO and the QBO, while the near-decadal timescale dominates the spectrum of BE hurricanes. Speculations as to the cause of the near-decadal oscillation of BE hurricanes center on changes in Atlantic SSTs possibly through changes in evaporation rates, perhaps as a result of changes in solar activity.

CLIMATE VARIABILITY IN ORENSE (SPAIN) IN THE LAST 300 YEARS

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Orense is an Spanish town placed in the Northwest of the Iberian Peninsula. Its meteorological station register data only since 1950, although Orense has the particularity of having an extremely ammount of historic documents with references to the weather of the town. The objective of this study is to reproduce two climatic variables (temperature and precipitation) for the last three centuries by means of historical sources and to analyze the climate variability. The great density of data permit us to know natural variability of climate in a single point

GLACIAL ATLANTIC SURFACE TEMPERATURES BASED ON NEW DATA AND A SEMI-INVERSE OCEAN MODEL

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A "SIMPLE ocean" model has been developed, which estimates surface currents in a diagnostic manner from surface winds. Horizontal heat transports by advection and diffusion and surface heat fluxes are used to calculated sea surface temperatures (SSTs). The unknown transports from the deep ocean are inversely calculated from sparse SST data. The model can be understood as a method to estimate a global SST field from a sparse data set, where it takes into account the wind driven surface currents.
In a control run for the modern ocean, SST data from the core top samples of about 200 CLIMAP sedimentary cores were used. The resultant global annual mean SST field matches the observations with a root mean square error of 1.85°C. A glacial run based on the glacial CLIMAP SSTs at the core sites already exhibited considerable deviations from the CLIMAP 2° × 2° interpolation in regions where no data existed.
For a second glacial run, new Atlantic core data provided by the Sonderforschungsbereich 313 in Kiel and the Sonderforschungsbereich 261 in Bremen have been used. The complete SST field estimated with the SIMPLE ocean model is presented and compared with the CLIMAP reconstruction.

PERSISTENCY OF LUNAR SIGNAL IN A PRECIPITATION DATA SERIES

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The phenomenon of dependence of precipitation amounts on the lunar phase (synodical month) has been studied since the 1960s in details by numerous authors in many countries, e. g. in Australia, Czechoslovakia, Italy and especially thoroughly in the USA. Data from thousands stations covering period of more than 50 years were subjected to rigorous tests with conclusion that the association of lunar phases with heavy rainfall is real. The statistical method applied in these works had often been a modification of method of superposition of epochs (MSE). The results proved that extreme precipitation events vary nearly simultaneously over all regions of the Earth and that they occur more frequently on the third to fifth day after syzygies. The concurrence and angular uniformity of the phenomenon have been questioned during last few years a that is base for this attempt to study statistical characteristics of results of MSE applied on a very long precipitation series of Prague-Klementinum (1805-1996). Despite largely shared belief of two-extremal course of mean precipitation during synodical month this study indicates that this is rather exceptional and that there are quasi-linear shifts on the curves of synodical signal with time scale of tens of years, not comparable with basic periods of lunar orbit.

THE FINE STRUCTURE OF THE SPECTRAL MAXIMA OF VARIATIONS OF SEA LEVEL,AIR PRESSURE AND AIR TEMPERATURE FOR PERIODS FROMSEVERAL DAYS TO SEVERAL MONTHS.

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The several broad maxima of spectrum of variations of sea level, air pressure and air temperature are existed inside the diapazone of periods from several days to several months. The periods corresponded to maximal values are located near to the same position for spectra of the air pressure, air temperature and sea level, which are recorded in the different points. The main maxima are located near to the period 15 days, 30 days , 45 days. We have analyzed the dependence of the form and positions of the spectral line on duration of the sample for case of the sample durations from 1 to 40 years in case of the points Holmsk (47.0 N,142.0 E) and Terney (45.1 N, 136.5 E) in time interval from 1950 to 1990. These maximal values are discovered for different samples if the sample duration is less than 1 year. For case of the sample duration more than 2 year the maxima are split for several separate maxima. If we increase the sample duration, the positions of the separate maxima do not change essential , but the widths of maxima get smaller and the heights of maxima increases. If the sample duration is more than 8 year this is the line spectrum . Instead of several maxima we have received the several groups of lines, strips. Each strip contains several lines. The distances between the lines of the separate strip are near to the the same and near to the value 2 pi / 365 1/day. The most essential lines of the second strip correspond to periods 27.3 and 29.5 days. These are the periods of the rotation of the Moon.

NORTH-ATLANTIC-EUROPEAN ATMOSPHERIC CIRCULATION CHANGES BETWEEN THE EARLY INSTRUMENTAL PERIOD AND THE RECENT CENTURY

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Within the EU-Project ADVICE ("Annual to Decadal Variability in Climate in Europe") changes of climate and atmospheric circulation since 1780 are investigated on the basis of early instrumental observations. Using monthly mean SLP grids for the North-Atlantic-European region reconstructed back to 1780 by Jones et al. (CRU 1997) an objective classification has been developped based on EOF and cluster analyses. Comparing the early instrumental period (1780-1860) with the recent century, changes in frequency and seasonal distribution are revealed for some of the resulting circulation patterns. Furthermore, some 72 temperature and 62 precipitation series, respectively, from Central Europe are used to select warm, cold, wet and dry months since 1780. SLP grids from these months are submitted to T-mode principal component analyses in order to derive basic circulation patterns associated with these climate anomalies. Comparing explained variances between the early instrumental period and the recent century gives indications about climate-related atmospheric circulation changes.

COMPARISON ANALYSIS OF SECULAR VARIATIONS OF SOLAR, GEOMAGNETIC AND METEOROLOGICAL PARAMETERS

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Long series of sunspot numbers and indices of geomagnetic activity from 1868 to 1990 have been examined by the method of cross-correlation analysis. Secular variations of the 23-year running correlation between the sunspot numbers and the parameters of geomagnetic activity with a characteristic period of about 50 years have been obtained. The selected secular variations of solar-geomagnetic coupling have been compared with long-term variations of two solar indices that are potential proxy measures for the solar irradiance: the length of the sunspot cycle and the Hoyt & Schatten's composite index. It has been shown that fluctuations of these indices relative to their linear trend change their sign in accordance with the secular variations of the solar-geomagnetic coupling. Long-term fluctuations of the Earth global land-air surface temperature anomalies relative to their linear trend have a period of about 50 years and show a good agreement with the secular variations of the solar-geomagnetic coupling.

RAPID CLIMATIC VARIATIONS AND MAGNETIC MINERALOGY CHANGES IN NORTH ATLANTIC SEDIMENTS.

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High resolution magnetic analyses of four cores located in the northern part of North Atlantic are presented. The cores are disctributed along an E-W transect between 60 and 62°N from the Faeroe islands (cores ENAM 93-21 and core MD95-2009), the Gardar drift (core SU90-33) and the Irminger basin (core SU90-24). The study has been focussed on climatic stage 3 during which variations in the low field magnetic susceptibility are correlated with temperature changes over Greenland as observed from the ice cores.
Changes in low field magnetic susceptibility illustrate variations in both concentration and grain sizes of magnetites and Ti-magnetites. The Heinrich events are characterized by low concentration of relatively fine grained magnetic particles. On the contrary, during interstadials 3 to 13 (Dansgaard-Oeschger events) high concentrations of relatively coarse magnetic grains are observed. The results of a high resolution (2 to 10 cm intervals) study of magnetic hysteresis parameters will be also reported and discussed
The possible origin for these variations in the magnetic properties of the sediment will be discussed in the known climatic framework of this region.

STUDY OF PERSISTENCE OF SSTA FROM ATLANTIC OCEAN BY MEANS OF MARKOV MODEL

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Monthly values of SSTA (Sea Surface Temperature Anomalies), defined in 522 points in the Atlantic Ocean (75^0W-10^0E,70^0N - 70^0S) in the period 1948-1994, have been analysed. The autocorrelation function which approximates the signal series is assumed that satisfies a Markovian process under the form C exp(- A|k|). In order to estimate C and A, the autocorrelation function was truncated until a lag where it becomes negative. In the paper, for each point, the decreasing rate (A), signal level (C), the effective time (T_0) and signal -to-noise ratio are presented and discussed. Concerning the T_0 values, which estimate the persistence level, in the Northern Hemisphere the values between 5 and 7 months are dominant, except for some areas situated between equator and 10^0 N, as well as around the latitude of 30^0 N ,where the persistence is lower than 5 months, while in the regions (45^0N - 60^0 N ; 45^0W - 20^0W) and (10^0N - 20^0N ; 70^0W-50^0W), the memory of SST anomalies is within the interval of 7 to 9 months with isolated points which have even 11 months.

CHANGES IN THE STRENGTH OF THE ICELAND-SCOTLAND OVERFLOW WATER IN THE LAST 200,000 YEARS: EVIDENCE FROM MAGNETIC ANISOTROPY ANALYSIS OF CORE SU90-33

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The anisotropy of magnetic susceptibility combined with mineral magnetic analysis is used as paleo-bottom current indicator. The degree of anisotropy illustrates the degree of preferential alignement of elongated magnetic particles, in turn related to the strength of the bottom current. Results are reported for core SU90-33 located (60°34'4N, 22°05'1W) at 2400m water depth along the Iceland-Scotland overflow water (ISOW). This core spans the last 6 climatic stages. The main magnetic mineral is low Ti-content magnetite with very slight downcore changes in the grain size. Both the susceptibility record and the changes of the proportion of smectite in the clay fraction are climatically controlled with lower values during glacial than during interglacial periods. The degree of anisotropy is significantly larger during interglacial periods than during glacial times. These changes provide evidence that the strength of the contour current associated to the transport of the ISOW appears to have been significantly larger during climatic stages 5, 3 and 1 than during stages 6, 4 and 2. Measurements in modern North Atlantic sediments will be also presented.

AFRICAN AND ASIAN MONSOON CHANGES AT 6000 BP INFERRED FROM A FULL COUPLED OCEAN-ATMOSPHERE MODEL.

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African and Asian monsoons were enhanced at 6 ka BP in response to an increased summer insolation. Simulations of the Paleoclimate Modeling Intercomparison Project (PMIP) reproduce this increase, but the northward extend of monsoon rain suggested by lakes and pollen data in North Africa is underestimated. PMIP simulations have been performed using atmospheric models with present day surface conditions. Part of the mismatch could therefore be attributed to the neglected feedbacks from ocean and vegetation.
Here, we investigate the role of the ocean in the 6 ka BP climate change using the IPSL (Paris, France) coupled ocean-atmosphere model with no flux correction at the air-sea interface. For the 6 ka BP simulation, only the orbital parameters have been changed and set to those of 6 ka BP, compared to the coupled control simulation.
The change in sea surface seasonal cycle helps to further enhanced the monsoon in Africa and Asia compared to simulations with the atmospheric model only forced by PMIP type surface conditions. Over Africa the coupling introduces a northward shift of the ITCZ over the continents which however is not sufficient to match the data.
The changes of meridional heat transport are opposite in the two fluids, the oceanic changes being larger except during the peak of the summer monsoon. In the Atlantic, the northward oceanic heat transport across the equator vanishes at 6 ka BP, but is relayed by the transport by the monsoon winds.

SEA SURFACE SALINITY RECONSTRUCTION OF THE INDIAN OCEAN DURING THE LAST GLACIAL MAXIMUM (ABOUT 18,000 YR B.P.)

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The oxygen isotope composition of planktonic foraminiferal tests includes contributions from sea surface temperature, global ice volume and local salinity. To reconstruct surface water salinity in the Indian Ocean at the last glacial maximum (about 18,000 yr B.P.) we have used the method developped by Duplessy et al., 1991. This method is based on a comparison between transfer function estimates of sea surface temperature and the oxygen isotope ratio of planktonic foraminiferal tests. For our study we have used a common planktonic foraminiferal species in the Indian Ocean, *G. ruber* . *G. ruber* is considered to live preferentially in the upper part of the euphotic zone (surface dweller) and to prefer warm conditions. We first used core-top analyses to demonstrate that, under modern conditions, the paleotemperatures determined from the isotopic composition of foraminiferal shells are linearly linked to the sea surface temperature of the warmer month. We then used this information to derive an estimate of the isotopic composition and salinity of the Indian Ocean surface water during the last glacial maximum. For the transfert function we have used ice age sea surface temperatures reconstructed by CLIMAP (1981). This sea surface salinity estimation enables us to reconstruct changes in the Indian Ocean monsoon and changes in sea surface circulation at the last glacial maximum in the Indian Ocean.

DYNAMICALLY CHARACTERISTIC OF THE ATMOSPHERE PARAMETERS DURING INTENSIVE MAGNETIC STORMS

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It is well known that Solar activity has a great influence to the upper atmosphere features. The alternation of corpuscular radiation strength, causes great changes of atmospheric parameters. The correlation between dynamically characteristic of the atmospheric parameters (air pressure, air temperature, humidity and quantity of falls) and variation of geomagnetic activity is presented. In this paper, authors established the correlation between average daily air temperature and index of geomagnetic activity (K) in time of intensive geomagnetic storms. That correlation is observed in the course of hours at days when magnetic storms are detected in Belgrade area.
Solar geomagnetic activity and temperature changes could be observed like external factors of increase number of calling from individual groups of diseases. In this paper, dynamical characteristic number of calling from KV diseases, psychosis, cancer of the lungs, in the time of intensive magnetic storms registrations, when big changes of air temperature have been registered in Belgrade.

CLIMATIC CHANGES IN THE LAST MILLENNIUM

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When the glacial eustatic sea level rise finished in Mid-Holocene time, a long-term deceleration in the Earth's rate of rotation ended, and, by that, the Earth came into a new dynamic mode where the feed-back interchange of angular momentum between the solid Earth and the hydrosphere got a dominant role for the distribution of heat (recorded in the regional paleoclimatic changes) and mass (recorded in the regional sea level changes) due to its effects on the ocean circulation. At around 800-1000 AD, the Earth's rate of rotation changed. This initiated - as the beating on a cord - a sequences changes between "Super-non-ENSO" condi-tions (around 950 AD), "Super-ENSO" conditions (around 1100 AD) and a second period of "Super-non-ENSO" conditions (responsible for the so-called Medieval Warm Optimum around 1250 AD). The cold periods in 1440-1460, 1687-1703 and 1808-1821 (or "Little Ice Ages") in relation to the Spörer, Maunder and Dalton sunsput minima seem all to represent similar oceanographic circulation changes in the North Atlantic and not any decrease in solar irradiance.

CLIMATIC RECONSTRUCTION IN EAST AFRICA FOR 6,000 YR B.P. FROM POLLEN DATA

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Comparisons of reconstructed paleoclimates from proxy-data with AGCM simulations provide a way to evaluate mechanisms of climate changes and to test how well models simulate the climates of the past. The 6ka time slice is a major focus of the paleoclimate modelling community. Africa is a key region to study changes in monsoon strength and extension through time. To provide quantitative and spatial estimations of the 6 ka climate in East Africa, we used three different methods : (1) the classic best analogues method ; (2) the best analogues method with a lake-level constraint ; (3) the plant functional type method based on a combination of pollen types grouped according to plant ecology.
A modern pollen dataset including 450 samples and a dataset of 33 pollen samples for 6 ka were used. The bioclimatic parameters reconstructed are the moisture index and the annual precipitation amount. Results shows an East Africa climate globally wetter at 6ka than today. This feature is consistent with the lake-levels which were higher than at present. Results are spatially consistent but the reconstructed climate for the sites located at very high elevation is less good.

1997 TEMPERATURES ARE HIGHEST ON RECORD: SHOULD IT BE ATTRIBUTED TO THE GLOBAL WARMING?

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Globally-averaged surface air temperature for 1997 appears to be the highest on record. This should not be necessarily attributed to the global warming, since in 1997 two (seemingly unrelated) positive temperature anomalies occurred: (1) a very large positive February-March anomaly over continental band 55-65 °N, apparently resulting from strong westerlies in the N. Atlantic and N. Pacific, and (2) the El Niño phase of the Southern Oscillation. From our calculations these two events contributed a substantial fraction of the global 1997 yearly anomaly.

INTERDECADAL CLIMATE VARIABILITY OVER THE NORTHERN BLACK SEA COAST ASSOCIATED WITH THE CHANGES IN THE COUPLED OCEAN-ATMOSPHERE SYSTEM

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The aim of the talk is to discuss the low-frequencychanges of the hydrometeorological and hydrographicparameters overthe coastal zoneof theNorthernBlackSeageneratedby the global changes in thecoupled ocean-atmosphere sytem. Regional archive ofthe Marine Hydrophysical Institute for 1950 to 1994was used for the analysis of high-amplitude decadaltointerdecadalvariabilityoftemperatureandsalinity in the N.W.Black Sea.The typical magnitudeof the decadal changes of monthlySST/SSSin thissea region is of 1C/1.5psu. High-correlated decadal-scale changes of the sealevelpressure over theNorth Atlantic, of the air temperature and precipi-tation over the Crimea, and of theBlack Sea riverdischarges in 1906 to 1994 were examined using mon-thly and yearly historical data sets.Our recent andearlier results shown that the decadal-scale varia-bility in the coupled system over the North Atlant-ic Ocean is due mostlyto the inherent changesofthe oceanic meridional heat fluxes there. The asso-ciated changes of temperature,pressure and cyclonicactivity over the Central/EasternEurope cause theBlack Sea coastal changes.

DANSGAARD-OESCHGER OSCILLATIONS: A HYDRODYNAMIC THEORY

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The millennium timescale climate variability that is so clearly evident through Oxygen Isotope Stage 3 of the last glacial cycle has come to be referred to as consisting of distinct Dansgaard-Oeschger oscillations. These appear in the oxygen isotopic time series derived from Summit Greenland ice cores as bundles which appear to define a "Bond cycle" whose characteristic period is approximately 10 kyr and which appear to be initiated by individual "Heinrich events". We have developed a series of models which explore the extent to which the D-O oscillation may be understood to be a natural mode of internal variability of the thermohaline circulation of the Atlantic ocean that exists under glacial boundary conditions. As we have shown (Sakai and Peltier, 1997, J. Clim.) our model of the THC actually "fibrillates" in response to the anomalous P-E forcing that is required to reduce the high latitude salinity to the low values that are known to characterize the glacial state. More recently this same Hopf bifurcation mediated transition has been shown to occur in a simple box model which is a modest extension of that originally introduced by Stommel. With the latter model it has also proven possible to acceptably mimic the Bond cycle by modulating the applied P-E anomaly in the way suggested by the repetitive nature of the Heinrich events.

GLOBAL AND REGIONAL OPTIMAL AVERAGES AND ASSOCIATED ERROR ESTIMATES OF ANNUAL OBSERVED SURFACE TEMPERATURE ANOMALY.

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Global and regional optimally averaged combined land air and sea surface temperature anomalies, with respect to 1961–90, are presented with their associated uncertainties. The optimum averaging procedure uses covariance EOFs of observed surface temperature anomalies, combined with data from the NOAA National Centers for Environmental Prediction Reanalysis over the poles, to specify their statistical structure. Input data were gridded annual 5° area Climatic Research Unit land air temperature and Meteorological Office Historical Sea Surface Temperature (MOHSST6) anomalies. The latter were first corrected before 1942 for changes in instrumentation with time. Estimates of the sampling uncertainty of each gridded anomaly, and the uncertainty of the instrumental corrections were input. The results are an average of the available annual data, combined according to their reliability and position with respect to the main modes of variability of the field, and an estimate of the possible error in this average allowing for all data-voids. Decadal average error estimates are calculated using annual errors. From this we can say that the decade 1988–1997 was significantly warmer than the decade 1978–1987 and all previous decades back to the 1860s.

COMBINED DYNAMICAL AND STATISTICAL MODELLING FOR THE INTERPRETATION OF IN SITU PALEO RECORDS

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Recent proxy data obtained from ice-core measurements, dendrochronology and valley glaciers provide important information on the evolution of the regional or local climate. General Circulation Models integrated over a long period of time could help to understand the forcing mechanisms (external and internal) of natural climate variability. For a systematic interpretation of local paleo proxy-records, a combined method of dynamical and statistical modelling is proposed. It is anticipated to simulate local paleo records by first undertaking a model consistent statistical downscaling and then use a forward modelling approach to obtain the behaviour of valley glaciers and the growth of trees under specific conditions. The simulated records can be compared to actual proxy-records in order to investigate whether e.g. the response of glaciers to climatic change can be reproduced by models and to what extent climate variability obtained from proxy-records (last millenium) can be represented. For statistical downscaling, a multiple linear forward regression model is used with the assumption that local weather conditions can be determined by large scale flow patterns of the atmosphere. For any locally observed weather parameter, sets of large-scale predictors at various pressure levels are used. It is found that daily data are required due to strong dependence on individual synoptic scale patterns. For development of the model, daily values of ECMWF-Reanalysis data are used. The results of the statistical model are then applied to a long integration of an ECHAM4 / Mixed Layer Ocean experiment and a GCM simulating preindustrial climate variability.

MULTIFRACTAL "NATURAL CLIMATE VARIABILITY"

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In order to detect a possible anthropic influence on climate one needs an accurate modelling of "natural climate variability". This modelling is usually done with a Gaussian noise, used as input into climate models. With a carefull scaling analysis, using wavelets, we show that various climate data show multifractal statistics: they are scaling and intermittent, with extreme events much more frequent than would give a Gaussian noise. This indicates that Gaussian noise or random walk strongly underestimate the variability. The latters are additive processes whereas multifractals correspond to multiplicative processes, displaying long-range correlations.

In the framework of this more realistic modelling of natural climate variability, it is quite possible that the recent "proofs" of human influence on climate no longer hold.

THE ROLE OF THE INDONESIAN THROUGHFLOW IN EQUATORIAL PACIFIC THERMOCLINE VENTILATION

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The role of the Indonesian Throughflow (ITF) in the ventilation of the equatorial thermocline of the Pacific Ocean is explored using a primitive equation ocean circulation model. Model results for a model domain with an open Indonesian passage are compared with runs for a closed Pacific domain. Three cases are presented: a run with no throughflow, a run with 10 Sv of imposed ITF transport, and a run with 20 Sv of imposed ITF transport. For each case the model is forced at the sea surface with seasonally varying wind stress fields, and surface heat fluxes are calculated using an atmospheric boundary layer model. Two idealized tracers are advected online to distinguish between thermocline waters of northern and southern origin which ventilate the equatorial thermocline. There are two principle findings to this study; first, that the mixing ration of northern to southern component waters in the equatorial thermocline is highly sensitive to the ITF transport, and second, that the sea surface temperature in the eastern equatorial Pacific exhibits a strong sensitivity to the ITF transport. The implications for thermal budgets in the Pacific Ocean are discussed.

18 KA BIOMES RECONSTRUCTED FROM POLLEN AND PLANT MACROFOSSIL DATA FROM NORTHERN EURASIA: PALAEOCLIMATIC INTERPRETATION

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Newly compiled pollen and plant macrofossil data from northern Eurasia were used to reconstruct vegetation of the last glacial maximum. That reconstruction was done with a quantitative method of biomization (Prentice *et al.*, 1996). At 18 ka tundra dominated a large area north of 57°N latitude at the place of modern cold deciduous and taiga forests. Cool steppe was reconstructed south of that latitude where cool mixed and temperate deciduous forests grow today. Taiga appeared northeast of the Black Sea, ca 1500 km south of its present limit in the European Russia, while in south-western Siberia taiga was reconstructed only slightly south of its southern limit today, suggesting the influence of the Scandinavian ice sheet was more pronounced west of the Urals. Broad-leaved trees were confined to the eastern coast of the Black Sea, where cool mixed and cool conifer forests reconstructed at 18 ka. The limited pollen data from central Asia and Mongolia do not provide evidences that vegetation was substantially differ from today. Reconstructed vegetation changes have been explained by the global cooling and change in the atmospheric circulation. Dry and cold north-easterly winds from the Scandinavian glacial anticyclone entered eastern Europe and southward shift of the westerly jet caused wetter conditions in southern Europe as far as western Georgia. These results are a contribution to the IGBP-PAGES sponsored Biome6000, PEPIII and PMIP projects.

LATEGLACIAL AND HOLOCENE CLIMATIC HISTORY IN GREAT BRITAIN FROM LAND SNAIL ASSEMBLAGES.

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Here we present a high resolution record from a Lateglacial-Holocene land snail succession from S.E. England. Temperature estimates, derived from the best analogues technique, indicate a cooling trend, between 14,500 and 12,600 cal BP, of 4° in summer and 8° in winter to the Younger Dryas event. The strong warming following the Younger Dryas stadial corresponds to increasing values of the same magnitude in 600 years. A cooling event, weaker than the Younger Dryas, of 1° in both seasons is recorded between 8,000 and 8,500 cal BP. These reconstructions from an European Holocene continental sequence are in agreement with fluctuations already described in North Atlantic, Mediterranean, and ice cores and African and Tibetan lakes records.

AN ANALYSIS OF ITALIAN LONG TEMPERATURE AND PRECIPITATION TIME SERIES

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A preliminary analysis of a number of Italian temperature and daily rainfall long time series is offered. After a preliminary investigation of time series homogeneity, the investigation is carried out in order to detect trends, abrupt changes or frequency peaks, indicators of climate change. A discussion of results is offered in the frame of climate model simulation output.

VARIATIONS OF THE DEUTERIUM EXCESS OVER THE LAST CLIMATIC CYCLE IN THE VOSTOK ICE CORE

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Isotopic records measured along polar ice cores are currently used to reconstruct paleotemperatures. In order to obtain additional information on the water cycle, attention has been more recently paid to the deuterium excess (d), defined as the deviation from the meteoric water line : $d = \delta D - 8\delta^{18}O$. Simple isotopic models have shown the dependency of d to the characteristics of the moisture source (sea surface temperature, relative humidity, surface wind speed).
We have measured a continuous deuterium excess profile over the last climatic cycle back to 150 kyr along the Vostok ice core. The d fluctuations are interpreted in terms of changes in the moisture origins.
A strong anticorrelation between d and obliquity suggests a modulation of high latitudes moisture sources by changes in sea ice extent.
High values of d during cold stage 5d compared with lower d values during cold stages 2, 4 and 6 could be explained by the superimposition of two effects at stage 5d : less moisture from the high latitudes (a lower atmospheric circulation at high latitudes), and more moisture from the low latitudes (tropical ocean still warm during stage 5d).

SEASONALITY OF LOW-FREQUENCY VARIABILITY IN EARLY-INSTRUMENTAL TEMPERATURES

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Earlier analyses of instrumental data (e.g. Briffa and Jones, 1993) showed the existence of season-specific features of natural climate variability on timescales up to a few decades. It is often argued that on longer timescales variability is independent of seasonality. We have addressed this issue by analysing the 7 long early-instrumental temperature records available for Europe. Spatially coherent oscillations are identified by applying (Multichannel) Singular Spectrum Analysis. Analysing summer and winter records separately, we found that the patterns of low-frequency variability (timescales larger than 50 years) are clearly season-specific. This holds both with and without the inclusion of the industrial segment. Winter temperatures show a slow warming, which is synchronous at all locations. Summer temperatures exhibit a timescale of about 150 years with a complex spatial pattern. Variability on this timescale is masked in the annual-mean data, because fluctuations in summer and winter tend to cancel. This implies that, also on longer timescales, summer and winter temperature patterns are controlled by different mechanisms. Consequently, networks of paleo proxies, which are used for reconstructing low frequency variability patterns, have to be seasonally homogeneous. Joint analysis of seasonally homogeneous paleo and early-instrumental data sets shows consistent variability patterns.

SENSITIVITY OF THE ATMOSPHERIC GENERAL CIRCULATION MODEL ECHAM 3 TO DIFFERENT GLACIAL SEA SURFACE TEMPERATURES

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Model-data comparisons within the Paleoclimate Modelling Intercomparison Project (PMIP) exhibit disagreements between the model output and the proxy data in some regions. These disagreements may either be caused by model inaccuracies or by unproper boundary conditions used by PMIP.
Here, the sensitivity of the atmospheric general circulation model ECHAM 3 to different boundary conditions for the last glacial maximum is investigated. In a first experiment the model is forced by CLIMAP sea surface temperatures (SSTs) as agreed upon within PMIP. For a sensitivity study the CLIMAP SSTs in the North Atlantic are replaced by new reconstructions of Sarnthein et al. Compared with the results based on PMIP boundary conditions, the changes of the model response to modified SSTs are very local and quite strong. Changes of the atmospheric parameters like surface air temperature occur mainly over the North Atlantic and Eurasian continent. The results of this investigation suggest that uncertainties in SST are important and may account for some of the model-data disagreements.

OA17 Climate variability: models and observations (co-sponsored by SE)

03 Climate variability: time scale interactions

Convener: Slingo, J.M.

SENSITIVITY OF THE CLIMATE OF A GCM TO THE BOUNDARY LAYER PARAMETERIZATIONS

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The sensitivity of the Global AGCM [1] to the parameterization of vertical diffusion in the boundary layer has been studied. Two PBL packages (Helfand and Labraga [2] and Z.Janjic [3]) are being compared in climatic runs for the two years 1987 and 1988 with prescribed sea surface temperatures. The sensitivity of the model's angular momentum cycle and poleward transport of energy, which are climatically of great importance was the main subject of interest in this study. These and other model properties for the two vertical diffusion schemes are compared both in long-term (2 year) runs and short-term (4 month) ensemble integrations.

[1] J.R.Bates, S.Moorthi, and R.W.Higgins, 1993: A global multilevel atmospheric model using a vector semi-lagrangian finite-difference scheme. Part I: adiabatic formulation. Mon. Wea. Rev., Vol.121, 244-263.

[2] Helfand, H.M., and J.C.Labraga, 1988: Design of a non-singular level 2.5 second order closure model for the prediction of atmospheric turbulence. J. Atmos. Sci., 45, 113-132.

[3] Janjic, Z.I., 1994: The step-mountain coordinate model: further development of the convection, viscous sublayer, and turbulence closure schemes. Mon. Wea. Rev., Vol.122, No.5, 927-945.

THE INTERACTION BETWEEN INTRASEASONAL AND INTERANNUAL VARIABILITY AND ITS RELEVANCE FOR THE SEASONAL PREDICTABILITY OF THE ASIAN SUMMER MONSOON.

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Using ECMWF and NCEP Reanalyses the dominant modes of interannual and intraseasonal variability have been identified. These show a common mode which describes the latitudinal displacement of the Tropical Convergence Zone from its oceanic to continental regime. On intraseasonal timescales this mode appears to describe the active/break cycles of the monsoon associated with northward propagating events. Using these results, the relationship between intraseasonal variability and seasonal mean anomalies has been investigated.

IMPACT OF SST FORCING ON THE MONSOONS OF 1987/88

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The interaction between ENSO and the monsoon was pronounced during the MONEG years 1987/88. Some of the AMIP simulations carried out with ECHAM captured the difference between the poor and the good Indian monsoon in these two years. The importance of the SST is investigated by rerunning the model without SST anomalies for different starting dates in early to late spring. Results for Indian rainfall and upper level velocity potential will be shown, and the importance of the SST forcing compared to impacts from, e.g. the land surface discussed.

SIMULATION OF INTERDECADAL HEAT STORAGES AND HEAT BUDGETS IN THE UPPER 400 m OF THE PACIFIC OCEAN

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We use a primitive equation isopycnal model of the Pacific Ocean to simulate and diagnose the anomalous heat balance on interdecadal timescales associated with heat storage changes observed from 1970-88 in the XBT dataset. Given the smallness of the interdecadal signals compared to the dominant ENSO signal, the agreement between model and observations is remarkably good and encourages future studies aiming to shed light on the poorly understood interdecadal timescale.

The interdecadal total (diabatic plus adiabatic) heat balance in the North Pacific Ocean is characterized by a complicated interplay of different physical processes, especially revealed in basin-scale averages of the the heat budget components which have comparable amounts of variance.

The diabatic heat balance north of 24°N, can be simplified to a balance between the tendency term , surface heat flux and meridional advection, the latter term dominated by anomalous advection of mean temperature gradients.

An important finding is the identification of two interdecadal timescales, roughly 10 y and 20 y, both similar to those reported by other investigators. The 20-y timescale is only present in diabatic heat budget components, while the 10-y timescale is present in both diabatic and adiabatic components. The role of the atmospheric forcing by surface heat flux is far more important for interdecadal timescales than for ENSO timescales.

DO WESTERLY WIND BURSTS LIMIT ENSO PREDICTABILITY?

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A conceptual model for ENSO is that of the Delayed Oscillator, according to which ENSO would consist in a redistribution of energy in the upper ocean with a timescale determined by ocean wave dynamics. Under this scenario, the tropical atmosphere would play a passive role, acting as a "slave" of the ocean. Several models that showed significant skill in ENSO predictions were based on these hypothesis.

Thanks to the great improvement of the observing system over the last decade it has been possible to monitor the development of a large El Nino event right from the beginning. The occurrence of strong westerly wind burst preceding (or triggering?) the onset of the 96/97 El Nino suggests that the high frequency variability of the atmosphere may play a more important role in ENSO than previously thought. This fact may have relevant consequences for seasonal predictability. The development of the 96/97 El Nino as analyzed and forecast by the ECMWF will be presented, and the role of the westerly wind bursts discussed.

COMPARING SIGNALS OF ENSO AND NAO FOR SELECTED REGIONS OF THE NORTHERN HEMISPHERE

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It has been demonstrated that ENSO phenomenon influences many climatic variables of different regions of the Earth. The North Atlantic Oscillation (NAO) has also some climatic effects. However the accuracy of estimating statistically the climatic variables using directly indices of Southern Oscillation and NAO indices are, limited due to, among others, the autocorrelation and multi-correlinearity among these variables. The main idea of the paper is to develop a relationship between those indices and large-scale patterns of atmospheric circulation over the area examined. Then an analysis of atmospheric circulation patterns (CPs) is used to explain the linkage between large-scale forcing and local climatic response via a conditional probability framework. Given such a relationship the accuracy of estimating local climatic variables from ENSO can be expected to increase. First, the CPs will be defined and the CP time series will be described. Then, the time series of hemispherical large-scale circulation will be compared for the different oscillation events. The frequency distributions of time series of CP types under different phases were compared. Then, for the new systems some climate parameters were compared. This procedure was used for midlatitudes in the Northern Hemisphere (Atlantic European and Western U.S. region).

A DYNAMICAL STABILIZER IN THE CLIMATE SYSTEM: A MECHANISM SUGGESTED BY A SIMPLE MODEL

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A fundamental question in climate research is that of how climate stability is maintained. A simple conceptual atmosphere-ocean model using parameterizations derived from observations has been developed which indicates that there may be a dynamical mechanism based on the poleward angular momentum transport (AMT) contributing to climate stability. A study of the observed seasonal variation of AMT across 30° N shows that it can be parameterized in terms of tropical-extratropical 500hPa height differences. The AMT is used to determine the surface winds and evaporation in the model. Infrared energy loss from the surface is parameterized in a way that includes the positive water vapour feedback. Analytical solutions are obtained which show that the dynamical feedback due to the AMT counteracts the water vapour feedback and holds the model climate stable.

INTRASEASONAL KELVIN WAVES IN THE TROPICAL PACIFIC

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Equatorial Kelvin waves are a prominent component of the intraseasonal variability in the tropical Pacific. While the linear theory of these waves has long been known many aspects of their behaviour, for example their relationship to ENSO, remain poorly understood. In recent years the development of the TAO array and the availability of accurate altimetry have greatly increased our knowledge of intraseasonal Kelvin waves. The use of this data in conjunction with numerical models offers an unprecedented opportunity for detailed study of these waves.

We have investigated the effect of ENSO on intraseasonal Kelvin waves with an OGCM forced with realistic surface fluxes. La Niña conditions reduce the west-east Kelvin wave transmission and Kelvin waves are slower during the cold ENSO phase. The intraseasonal Kelvin waves are more strongly damped during La Niña, due to increased viscosity, (resolved) eddy energy transport by Tropical Instability waves, and downward energy propagation. Partial reflection off the west-east sloping thermocline may also account for some reduction of the Kelvin wave amplitudes in the eastern Pacific. There is no evidence for wave breaking, or energy transfer between the baroclinic modes.

A STUDY OF SCALE INTERATION IN THE ANOMALIES EQUATORIAL ATLANTIC

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Different simulations of the interanual variability of the tropical Atlantic are intercompared. While the evolution of the episodic warmings/coolings is monitored through the zonal and meridonal sea surface temperature anomalous gradients, the generation of the events is better represented in terms of the anomalous heat content of the surface layers. Thorugh model output statistics, this heat content can be related to other features of the simulation, like mixed layer depth, or surface currents. The interaction between scales is studied, by including among other variables, some derived from the forcings (anomalous wind stress and curl) through integration.

THE INFLUENCE OF MIDLATITUDE OCEAN/ATMOSPHERE COUPLING ON THE LOW-FREQUENCY VARIABILITY OF A GCM WITH TROPICAL SST FORCING

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In this study we investigate the impact of midlatitude ocean/atmosphere interactions on the atmospheric circulation and, in particular, on the extratropical response to ENSO-type forcing. Two GCM simulations with and without an interactive mixed-layer ocean in midlatitudes and with realistic SST variability in the tropical Pacific are performed. We find that midlatitude coupling alters the spatial organization of the atmospheric low-frequency variability in qualitatively the same manner (but not to the same extent) as tropical SST variability, namely by selectively enhancing certain of the pre-existing (natural) dominant modes without significantly modifying them or generating new ones. While tropical SST forcing results in a notable amplification of the PNA mode of the model, midlatitude coupling appears to favor the regional zonal index circulations in the eastern and western Pacific. As a result, coupling qualitatively modifies the structure of the extratropical response to ENSO-like tropical SST forcing by conferring Western-Pacific-like characteristics to this remotely forced signal, thereby improving its resemblance to the observed ENSO teleconnection pattern, while weakening its projection onto the PNA mode. Coupling also increases the persistence of the overall signal. The simulated covariability in the Pacific sector possesses the same kind of interannual/intraseasonal duality exhibited by the observations. This implies that two-way air/sea interactions and ocean dynamics may not play an essential role in determining the large-scale spatial structure of the observed dominant modes of covariability.

A ESTUDYN OF HYDROLOGIC VARIABLITY OF DOURO RIVER BASIN

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Recently, the study of climate variability in the Iberian Peninsula has attracted considerable interest. Knowledge of behaviour and evolution, in space and time, of the mathematical series, which correspond to the different climate elements, is important due to its social and economic repercussions. In this respect, the flow series and precipitation series are of particular importance.

In this study, the variability exhibited by those series at the Douro River Basin, as well as the analysis of the principal rotated and unrotated components series and precipitation series are investigated.

Flow and precipitation have been simulated as a function of both altitude and the estimated laplacian of the altitude. The results obtained with the models allow us to relate flows and precipitation to the geographic pattern of the region.

The application of spectral method (Rapid Fourier Transform) have also shown oscillations which are characteristic of flow and precipitation.

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ON LONG EQUATORIAL WAVE REFLECTION

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Long equatorial wave reflection at the Pacific ocean boundaries are studied over the period October 1992-April 1997 using TOPEX/POSEIDON sea level and ERS wind stress data. At the eastern boundary, Kelvin waves are observed to reflect into first-mode Rossby waves with a reflection efficiency of 75% of that of an infinite meridional wall. However, reflected long Rossby wave amplitudes are observed to decrease strongly while propagating westward. Indeed, west of 110W, the Rossby signal is mainly dominated by wind forced Rossby waves and not by Kelvin reflection at the eastern boundary. This result dismisses the role of eastern boundary Kelvin wave reflection as a major contributor to the Rossby signal in the central Pacific. At the western boundary, the reflection of the first two Rossby waves does explain most of the Kelvin wave variance. The large contribution of the second Rossby wave reflection to the Kelvin wave illustrates the crucial role played by the Papua-New Guinea asymmetric coasts close to the equator. A spectral analysis of the wave and wind signals in the western Pacific shows that the first three Rossby waves propagating west of the dateline are mainly wind forced near the dateline at periods of two to four years. Finally considering only the low-frequency component of the wave signal, the reflection efficiency at the irregular western Pacific ocean boundary (mainly the Borneo/Indonesia/Asia and Australia/New Guinea land masses) is estimated to be around 50% of that which would be reflected from a solid meridional wall.

A GENERICALLY INTRASEASONAL SOUTHERN OSCILLATION OF THE ATMOSPHERE–LAND SYSTEM?

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The Southern Oscillation (SO) has recently been found to possess a structured low-frequency (LF; 4–7 year) band. Coexistence of at least two related modes throughout the century has been confirmed by the present author in a study of the modal structure of Indian monsoon time series. There is reasonable suspicion that one of these modes might correspond to a phenomenon found a couple of years ago in an in–depth empirical study of the attracting manifold of a coarse–resolution, two–layer, tropospheric General Circulation Model (GCM): A self–maintaining, generically intraseasonal Southern Oscillation of the atmosphere–land system that develops at the GCM's attractor sets under boreal post–midsummer conditions—although temporally fixed SST fields are applied. The nature, occurence and performance of this SO and of its interannual LF 'daughter' mode are presented in detail, and Indian summer monsoon (ISM) as well as SO time series of the GCM are analyzed in view of their respective interannual to interdecadal modal structures. Internally generated, centennial–scale variability that exhibits 'epochal' character is traced back to constructive interaction across the annual forcing scale of ISM retreat dynamics resulting in a biennial mode, the annual forcing itself, and the SO. Preliminary comparison to observed modal structures of both ISM and SO is made in view of a potential method of GCM verification.

ON THE MODAL STRUCTURE OF INDIAN MONSOON ONSET

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As start-up of a two-week episode that results in establishment of the Indian summer monsoon (ISM), onset over Kerala (MOK) is not only an economically important reference signal but signifies also a key singularity of the global seasonal cycle. Sampled annually once at intersection between climate regimes, monsoon onset and retreat series are generally viewed here to represent natural Poincaré sections that might help dismantling topologically relevant climate information. A complex dynamical picture is inferred from the scarce data base provided by high-quality MOK, northeast monsoon onset (NEMO), and ISM retreat series which are available for different timespans of the 1870–1990 period. Synchronized with an 8 year mode, the densely populated 2–3 year band exhibits three marked components centered by a 2.24 year mode that leads NEMO. A relatively strong 11 year NEMO mode is growing throughgout the century. Prominent MOK modes of the 4–7 year band are argued to belong to distinct atmosphere–land and atmosphere–ocean oscillators. MOK/NEMO phase relationships carried by the latter underwent systematic changes during the 20th and 50th, apparently controlled by modified beat periods. Both sunspot and double (Hale) cycles appear to be unimportant in the dynamic organization of the climate system as reflected in these series. Frequency relationships and their changes tend to follow selection rules of the Farey (continued-fraction) tree. Two climate fluctuations of the century, standing out as shifted means in both MOK and NEMO, indicate decadal-scale interhemispheric mass displacement apparently related to the status of the North Atlantic Oscillation.

GLOBAL CIRCULATION PATTERNS ASSOCIATED WITH ATMOSPHERIC FORCING BY SEA SURFACE TEMPERATURE

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In this study an assessment is made on the interannual variability of the atmospheric circulation simulated by an R21 version of the Melbourne University AGCM. For this purpose, covering the period 1979-88, an ensemble of 10 independent simulations has been produced, the model being forced by prescribed fields of observed sea surface temperature and sea ice cover. Internal and forced variabilities were analysed throug use of a 3-D normal mode expansion scheme of geopotential and wind fields, allowing a separation between barotropic and baroclinic as well as gravitic and rotational components. A complex principal component analysis (C-PCA) was then performed on barotropic and fourth baroclinic modes, associated with both internal and forced variabilities. With respect to modes associated with internal variability, the PNA teleconnection pattern appears as the first global EOF for both barotropic and fourth baroclinic modes. In the case of modes associated with forced variability, C-PCA reveals as first EOF patterns resembling the one proposed by Karoly (*1989, J. Climate, 2*) in the case of barotropic and the Walker Circulation in the case of fourth baroclinic mode. PCs associated with two forced patterns present high values of correlation (resp. 95% and 97%) with the *cold tongue* El Niño index. Results of projections of global NCEP reanalysis (1973-96) onto forced patterns, as well as correlations with an El Niño index, will finally be presented.

ROLE OF INDIAN OCEAN SSTs ON THE ASIAN SUMMER MONSOON

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There is evidence that a link exists between ENSO and the Asian summer monsoon, but the mecanism is not known clearly, particularly the respective parts of variability of the monsoon explained by remote or local impact of the SSTs. For the third year of the EEC funded SHIVA project, we propose to investigate the role of Indian ocean SSTs on the summer monsoon. For this purpose, we run the ARPEGE/CLIMAT GCM, developed at Météo-France. The model is forced with composite global SSTs. These composite fields are based on all the 9 possible combinations of climatological SSTs, 1987 and 1988 observed SSTs specified separately for the Indian and Pacific ocean basins. A T31 troncature (grid spacing of 3.8°) has been choosen for this experiment, giving a satisfactory representation of the Asian summer monsoon at a low computational cost. The period of integration starts on the last day of February and finishes at the beginning of October, so as to cover the entire period of the Asian summer monsoon, including onset, mature phase and retreat.

TIME SCALE INTERACTIONS OF SST VARIABILITY IN DIFFERENT GCM SIMULATIONS

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Analyses of monthly mean sea surface temperature (SST) from different coupled global circulation models (GCMs) were conducted. The simulations employ a hierarchy of ocean and atmosphere models which differ in the spatial resolution and in the processes simulated in the ocean models. The frequency spectra of the SST anomalies are basically dominated by the red noise characteristics of a AR(1)-process, but the GCM simulations also show signifcant differences from that of a AR(1)-prozess over large regions. In general, a steeper slope relation to the expected omega to power(-2)-slope is found in the GCM simulations. This can be attributed to internal low frequenzy variability of the atmosphere and/or to atmosphere-ocean interactions. The differences due to atmosphere-ocean interactions are important for interannual and decadal SST variability and predictability. They will be further investigated and discussed in this talk.

THE INFLUENCE OF SOLAR VARIABILITY ON THE VARIABILITY OF THE CLIMATE SYSTEM

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The role of solar variability as a cause of decadal to centennial climate change is still a topic of debate. We assess the response of a coupled General Circulation Model (GCM) to an estimate of the solar variability since 1700, and to a series of idealized sinusoidal solar forcings with periods ranging from 11 to 160 years and amplitudes ranging from 0.5 Wm^{-2} to 6.0 Wm^{-2}, superimposed on a constant forcing of 1365 Wm^{-2}. The reponse to a variable solar forcing is compared to the internal variability resulting from large-scale ocean-atmosphere-sea-ice interactions. It is found that locally, and on the regional scale, the internal variability dominates and that a variable solar forcing hardly affects the dominant modes of variability and their explained variance. On the continental to global scale however, and averaged over periods longer than 30 years, the solar-induced variability dominates internal variability in the averaged, annual mean surface air temperature (SAT). This seemingly contradictionary result can be explained by the fact that the internal modes of variability are only weakly correlated with changes in globally averaged, annual mean SAT. The latter is a consequence of the structure of all the internal modes of variability, which are characterized by patterns of both positive and negative temperature anomalies.

HIGH AND LOW FREQUENCY INTRASEASONAL VARIANCE OF OLR ON ANNUAL AND ENSO TIME SCALES

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Using 20 years of outgoing longwave radiation (OLR) observations, the complex behaviour of the higher (6-25 day) and lower (25-70 day) frequency bands of tropical intraseasonal convective oscillations is investigated over the tropical and subtropical Indian and Pacific Oceans (including Australasia). Emphasis is given to the mean annual cycle and to the interannual variability of both bands on ENSO time scales, as well as to the interaction between the two bands. The strongest intraseasonal signals are, for the most part, aligned with the Intertropical Convergence Zone (ITCZ) and South Pacific Convergence Zone (SPCZ). In some cases, the 6-25 day signal is not co-located with the Madden-Julian Oscillation (MJO) signal and/or occurs remotely from the ITCZ. Over the equatorial eastern Indian Ocean, strong activity in both bands persists throughout the year, but the bands are found to be anti-correlated, regardless of the ENSO phase.
The effect of ENSO time scales is further examined by looking at DJF anomalies for five El Niño and two La Niña events during our 20-year sample. A well-defined response of the two bands is restricted to the northwestern and central Pacific. Over the northwestern Pacific Ocean the two bands complement one another with suppressed (enhanced) convection occurring during El Niño (La Niña) events. Both bands also complement each other over the equatorial central Pacific, but are out-of-phase with those in the western Pacific on ENSO time scales. In contrast, over the Australian monsoon region and the eastern Indian Ocean, neither band shows a uniform response in terms of anomalous activity when the latest five ENSO warm events, 1977-78, 82-83, 86-87, 91-92 and 92-93, are considered.

QBO SIGNALS IN THE MONSOON SYSTEM IN GCM EXPERIMENTS

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In order to study the relationship between the QBO and the monsoon system, GCM experiments have been performed, using the ECHAM4 T42-L19 model, where the QBO was assimilated by a linear relaxation technique. A comparison of experiments with opposite phases of the QBO, but otherwise equal boundary condition, showed a linear relationship between the change in cloud amount and change in temperature at 100 hPa in regions of deep convection. The QBO related signal in OLR cloud forcing reinforces the QBO induced temperature signal at the tropopause further, thus providing a positive feedback mechanism. The resulting difference in precipitation between the easterly QBO and westerly QBO experiments reaches 100 to 150 mm/month in the equatorial Indian Ocean in winter and in the tropical western Pacific in summer. Thus the experiments show that the QBO, which is driven by tropical waves with periods of a few days, contributes substantially to the interannual variability of the monsoon system. This may help to explain observed biennial components of the variability of the tropospheric circulation.

MODIFIED ERTEL'S POTENTIAL VORTICITY AS A CLIMATE VARIABLE

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Existing arbitrariness in Ertel's potential vorticity (PV) definition is used to arrive at an "optimal" PV modification which refers to minimum (in the least squares sense) of the material time-rate of change of PV due to diabatic heating an friction. Simultaneously, a problem of determination of an idealised atmospheric climate state with the highest possible degree of annihilation of diabatic and frictional PV forcing is solved. A minimisation procedure is applied to a difference of informational entropy (IE) values between actual air mass distribution on PV values over each Hemisphere and the corresponding statistically equilibrium (Boltzmann) distribution and used for searching for optimal PV definition. Method efficiency is shown, using monthly-mean January and July statistics for 1980-89 years period (ECMWF data). Interannual variations of statistical characteristics of the optimally modified PV field are analysed and related to air changes over Antarctic and Arctic in the 1980s.

THE INTERANNUAL VARIABILITY OF THE MADDEN-JULIAN OSCILLATION IN AN ENSEMBLE OF GCM EXPERIMENTS.

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The interannual variability of the Madden-Julian Oscillation (MJO) is investigated in an ensemble of 15 experiments performed with the ECHAM4 T30 GCM. The model experiments have been performed with AMIP conditions from January 1979 to December 1993. The MJO signal has been identified by means of a Principal Oscillation Pattern (POP) analysis applyed to the normalized ensemble anomalies of the 200-mb equatorial velocity potential.
Some evidence of a sensitivity of the simulated MJO activity to the sea surface temperature (SST) over the equatorial Indian Ocean and Pacific is found. The interannual variability of the simulated oscillation, in fact, appears to be significantly correlated with the equatorial SST in the Indian Ocean. The results indicate also a clear influence of the El Nino/Southern Oscillation phase on the spatial distribution of the intraseasonal oscillation activity . During the warm phases of ENSO, the largest activity appears to migrate eastward into the central Pacific, whereas, during the cold phases, the strongest activities are confined in the western Pacific.

CONTRIBUTION TO THE ANALYSIS OF IBERIAN PENINSULA CLIMATE VARIABILITY

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The atmosphere and its climatic mean state are constantly evolving on many time and space scales. Our research in Iberian Peninsula is devoted to identifying regimes on intermediate time scales, on the order of several years to decades, in the hope that their presence can be used for understanding and possibly predicting climate fluctuations.
The method of principal component analysis is applied to link together spacial and temporal components of air temperature and precipitation in Iberian Peninsula. The variability of these climatological fields are broken into several orthogonal patterns, each one explaining a fraction of the total temporal variance. These ranked patterns are analysed and possible physical processes are assigned to the predominant eigenvectors.
A selected network of more than one hundred weather stations with records between 1960 and 1990 is used as data base to isolate the principal modes of variability of temperature and precipitation fields in Iberian Peninsula.

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ASSESSING THE INFLUENCE OF ENSO FORCING ON SYNOPTIC ACTIVITY IN THE TROPICAL ATLANTIC.

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The tropical Atlantic Hurricane season of 1997 was unusually inactive. Given that the Sea Surface temperatures (SSTs) in the tropical Atlantic were slightly warmer than the long term mean during the Hurricane season, this is somewhat surprising. It has been suggested the large amplitude El Niño, occurring simultaneously in the tropical Pacific, contributed to the relative inactivity in the Atlantic. Physical mechanisms for how this can occur are unconvincing. A hierarchy of General Circulation Models and high resolution Limited Area Models along with available observational data sets, will be used to assess the influence of the tropical Pacific on the tropical Atlantic . Results will be reported indicating by which mechanisms anomalies in the tropical Pacific SSTs can directly influence synoptic activity in the tropical Atlantic.

Sensitivity to resolution studied with a variable horizontal resolution global circulation model

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The atmospheric general circulation model ARPEGE used at METEO-FRANCE for climate studies is a spectral model that offers the possibility of varying the horizontal resolution. This allows to increase the resolution over the region of interest while keeping a reasonable cost in computer time.However, this technique may be non-isotropic when the contrast between the highest and the lowest resolution of the streched grid is strong. This problem becomes critical when the model's physical parametrizations are quite sensitive to the horizontal resolution. In the present study, numerical simulations are performed with the stretched version of ARPEGE-Climat in order to investigate the resolution dependence of moist processes and precipitation simulated by the variable resolution model with idealized boundary conditions corresponding to an "aquaplanet". The Earth is covered with an ocean whose prescribed surface temperature has a zonally symetric latitudinal distribution. Simulations bring to the fore some disymetric structures along the equator, due to the varying resolution. Such results are very sensitive to the choice of some physical parameterizations, such as the cloud scheme or as the closure's condition in the convective scheme.

SEASONAL FORECASTS WITH A COUPLED AOGCM.

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Research activities have been conducted at Météo-France in the field of seasonal predictability with ARPEGE atmospheric GCM, as part of PROVOST program. In these studies ARPEGE is forced with analyzed observed SST.

A new set of experiments have been recently realized in order to determined the impact on long-range predictability when ARPEGE GCM is coupled with the LODYC-OPA7 ocean model, but only over a limited area (the tropical Pacific region "TDH"). We have studied 4 winter cases (JFM averages from 1990 to 1993, after a December spin-up period). There is 9 experiments for each year, with a shift varying from 1 to 9 days before the 1st December, for both atmospheric and oceanic restarts.

Results will be presented and comparisons will be made between the two set of uncoupled and partially coupled experiments, in terms of

(i) possible seasonal drift induced by changes in SST over the coupled area ;

(ii) probable increase in intra-seasonal variability caused by the new degree of freedom brought by the coupling ;

(iii) expected change in the objective scores computed when comparing the climatology and the experiments.

THE DYNAMICS OF EURO-ATLANTIC BLOCKING ONSETS

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The low-frequency extratropical variability is highly influenced by the occurrence of some particular large scale circulation flow patterns, the weather regimes. The mechanisms leading to one of those regimes, the euro-atlantic blocking, are investigated using observed data and outputs of a simple QG model. A large scale and small scale composite analysis indicates that euro-atlantic blocking events have two simultaneous precursors identified on both observed and simulated data: a high latitude retrograding wavenumber one pattern at planetary scale and an enhanced baroclinic wavetrain traveling across North Atlantic at synoptic scale. The question whether the two above precursors are necessary and sufficient conditions to trigger euro-atlantic blocking is addressed by performing various sets of initial-value experiments performed with the quasi-geostrophic model.

RELATIONS BETWEEN NAO, PNA, AND ENSO OSILLATIONS IN SEASONAL WINTER SIMULATIONS WITH FOUR AGCMs

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In the framework of the European project PROVOST (PRediction Of climate Variations On Seasonal and interannual Timescales), nine simulations of each of the winter seasons of the period 1980-1994 have been performed with four different atmospheric models in SST-forced mode : the UKMO model, the ECMWF model, Arpege Climat model of Météo-France (T42), and Arpege Climat with a higher resolution of T63 (this latter set of simulations being calculated at EDF). This provides an important multi-model ensemble to study the reproduction of the main low frequency oscillations occuring at extratropical latitudes (PNA and NAO patterns) and their possible modulation by different oceanic factors. We identify clusters or modes of atmospheric low frequency variability in these sectors and we look for typical structures of the oceanic forcing associated to each of these atmospheric patterns. A particular attention is paid to the possible modulation of the NAO by different possible external sources : NAO-PNA interactions, extratropical or tropical oceanic forcing influence on the NAO (in particular : interactions with the three El Niño and one La Niña events involved in the period studied).

ON THE INFLUENCE OF NORTH ATLANTIC SST ANOMALIES ON THE ATMOSPHERE

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A satisfactory understanding of how mid-latitude SST anomalies influence the atmospheric circulation has remained remarkably elusive. Past studies of this problem have yielded divergent results. There is, however, a good deal of evidence to suggest that the time mean reponse can only be understood by reference to changes in the high frequency transients; that is, to changes in the frequency, intensity, or spatial distribution of mid-latitude weather systems.
We are investigating the influence of SST anomalies on the statistics of Atlantic weather systems. We have carried out a large ensemble of integrations with the UKMO atmosphere GCM and are focussing in particular on the influence of SST anomalies in a key region of cyclogenesis off the SE coast of the U.S.A. Changes in sensible and especially latent heat flux in this region due to changes in SST could modulate the strength of the North Atlantic Storm Track which could influence low frequency variability such as the North Atlantic Oscillation. We will report results from seasonally varying integrations through the northern mid-winter and spring.

THE ROLE OF LAND SURFACE PROCESSES IN INTERANNUAL VARIABILITY OF THE LMD GCM.

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The Asian Monsoon displays substantial interannual variability which has profound social and economic consequences for the people of India and South East Asia. An understanding of the causes of this interannual variability is central to future success in seasonal and longer term prediction. The aim is to diagnose interannual variability in the LMD GCM and to explore the links between the regional and large scale aspects of interannual variability. Various mechanisms have been proposed to explain the interannual variability of the monsoon. These include land surface processes and Eurasian snow cover. Although weak monsoons are frequently associated with El Niño, the correspondence between the strength of the rainfall and the strength of ENSO is relatively weak. Part of the variability in this relationship may result from other slowly varying boundary conditions, such as soil moisture, vegetation and Eurasian snow cover. The aim of this study, is to identify the role of land surface processes anomalies, particularly in the months preceding the monsoon, in determining the interannual variability of the monsoon, including their relationship with ENSO.
The results of an ensemble of six integrations for the years 1950-1994 with the complex land surface scheme (Sechiba) and an integration for the same years with a simplified land surface scheme are used. Our aim is to characterize the forced and internal variability and the impact of the change in land surface processes on these vari abilities.

NATURAL CLIMATE VARIABILITY ON ALL TIME SCALES FROM A STOCHASTIC ATMOSPHERE-OCEAN MODEL

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After removing annual variability, power spectral analyses of local atmospheric temperature from hundreds of stations and ice core records have been carried out from time scales of 10^{-2} to 10^{6} yr. A clear sequence of power-law behaviors is found as follows: (1) from 40 ky to 1 My a flat spectrum is observed, (2) from 2 ky to 40 ky the spectrum is proportional to f^{-2} where f is the frequency, and (3) below time scales of 2 ky the power spectrum is proportional to $f^{-\frac{1}{2}}$. At time scales less than one month we observe that the power spectra of continental stations become proportional to $f^{-\frac{3}{2}}$ while maritime stations continue to have power spectra propotional to $f^{-\frac{1}{2}}$ down to time scales of one day. To explain these observations, we model the vertcial transport of heat in the atmosphere as a stochastic diffusion process. The power spectrum of temperature fluctuations at the earth's surface expected from this model equation in a two-layer geometry with thermal and eddy diffusion properties appropriate to the atmosphere and the ocean and a radiation condition at the top of the atmosphere agrees with the observed spectrum. This model can be used as a null model against which to test for the presence of periodicities and anthropogenic effects on the climate system.

COUPLED MODES OF VARIABILITY BETWEEN SURFACE TEMPERATURE IN PORTUGAL, 500 hPa HEIGHT AND SEA-LEVEL PRESSURE

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A long-term climatological analysis is performed over non-seasonal standardised monthly means of surface temperature at 15 stations in Portugal, 500 hPa height (Z500) and sea-level pressure (SLP) for a region including North Atlantic and Western Europe, covering a period of 34 years from June 1955 to May 1989. A Principal Component Analysis was performed and, as expected, leading PCA modes showed to be in good agreement with the synoptic-climatological experience as well as with results from previous works. In order to relate surface temperature variability with large scale circulation characteristics, a direct Singular Value Decomposition (SVD) as well as a Canonical Correlation Analysis (CCA) were applied to surface temperature and either Z500 or SLP fields, allowing to isolate pairs of spatial patterns that tend to synchronously occur. A multiple linear regression model was then developed between first PC of temperature and two sets of three best correlated PCs of Z500 and SLP. The CCA was used as the fitting process, obtained canonical correlation coefficient reaching 65% for the first mode. Predictions were performed and obtained values of statistics that measure forecast skill indicated acceptable results. Quality of obtained predictions using a cross validation scheme was finally evaluated through use of skill scores, allowing to conclude that this model has a better performance than either climatology or persistence.

VARIABILITY AND INTERACTION OF THE GLOBAL ATMOSPHERE CIRCULATION FORMS OVER THE ATLANTIC AND EUROPEAN SECTORS OF THE NORTHERN HEMISPHERE IN WINTER

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Investigation of the synoptic and global variability of the atmosphere circulation types over the Atlantic and European parts based on the parameters of the middle troposphere carried out. We considered the consecutive change of the various types of the atmospheric processes using Dzerdzeevsky's classification. Indexes of the atmosphere circulation calculated by the different methods were studied as one of the important characteristics of the predominant circulation regime. Amplitude-phase characteristics of the indexes were accounted by using original method proposed by Reva (1995).
We studied as simple circulation mechanisms make zonal and meridional types of the atmospheric processes. The results allowed to determine structure of the natural synoptic seasons and distinguish the intraannual stages of the atmospheric processes. Such approach gave us a possibility to investigate the characteristics of the winter circulation epochs over the Atlantic ocean and Europe for the period from 1950 to 1990.

THE RECENT ABATEMENT OF EASTERLY WINDS IN THE NORTHERN ADRIATIC

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Easterly winds from the northern Adriatic contribute, together with atmospheric depressions and the often decisive blowing of southerly winds from the southern and middle Adriatic, to produce damaging sea surges in the Gulf of Venice. A new statistical analysis of three-hourly wind records from Trieste for the period 1951-1997 has shown a clear decline in the strength of bora and other easterlies. This abatement is not accompanied by a strengthening of winds from other directions, but by more frequent calm situations (from 26% of total observations in the 1950s to 44% during the last ten years, and even to over 60% during the early 1980s). Similar (though weaker) declining trends for the easterlies have been recorded at other stations in the northern Adriatic (Ronchi, Venice). An inspection of previously published data from Trieste suggests that such trends may have been going on, possibly with minor fluctuations, since at least the beginning of regular instrumental records, in the late 1860s. Such changes in wind pattern, which have favourable effects on the frequency of coastal flooding, may be due, at least in part, to interdecadal climate variability. However, the persistence of certain trends suggests variability over a longer time scale, with in particular less frequent situations with strong atmospheric pressure gradients between highs in central/eastern Europe and lows in southern Italy or in the Adriatic area.

INTERANNUAL VARIABILITY OF THE OCEAN-ATMOSPHERE SYSTEM THROUGH GLOBAL GENERAL CIRCULATION MODEL RESULTS: THE PACIFIC OCEAN

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A Coupled General Circulation Model is used to study the interannual variabilty of the climate system of the global domain with a focus on the Pacific Ocean. Two simulations are analysed in order to compare the effects of the parametrisation of the lateral diffusion in the ocean model (horizontal versus isopycnal diffusion).
Sophistaticated analysis tools such as Multichannel Singular Spectrum Ananlysis and Canonical Correlation Analysis are used to perform these analyses.
We focus our attention on the El Niño phenomenon particularly present in the isopycnal run. The goal of the work is to better understand the processes responsable for the spatial and temporal pattern of the phenomenon. The two simulations, differing only by their ocean physics, don't show the same oscillations. It can attributed to a different mean state and to the dynamics associated with the isopycnal diffusion. In this way, the role of the salinity may be non negligeable. The connections with the northern and southern midlatitudes are also discussed.

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SOME QUANTITATIVE SIGNATURES OF CLIMATE VARIABILITY ON TIME SCALES OF SOLAR FORCING

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In spite of advanced knowledge in the field of weather systems, the adequate climate scenarios intend deeper insight into the drivers of climate changes. The overcentennial records available for such meteorological parameters as an air temperature T and precipitation totals P allow to judge their evolution on time scales of solar forcing, a quantitative basis being applied. The interannual, annual, decadal and secular variations are discussed from the viewpoint of possible modulation. Although the uncertainties are significant enough due to quite a large scatter of ΔT and ΔP fluctuations, the modulation features in their profiles are unambiguous and persistently documented by data from a number of European meteorological stations. Their mutual comparison in terms of peculiarities of T and P development averaged within different portions of a year gives some idea as to the ways how to enhance the confidence level of prediction of climate changes in future.

THE ENSO SIGNATURE ON WINTER RAINFALL OVER THE IBERIAN PENINSULA

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The strong ENSO event currently underway has been drawing much attention due to its impacts world-wide. This study investigates de influence of the ENSO phenomenon on the winter rainfall over the Iberian Peninsula. The analysis is based on observed rainfall data and on an ensemble of ten 10-year long simulations with prescribed AMIP SSTs and sea-ice coverage generated by the Melbourne University General Circulation Model (MUGCM). Each of the 10 simulations started from different initial conditions randomly obtained from an earlier 30-year control simulation. Results show that, in average, ENSO is associated with weak negative regional rainfall anomalies (-10 %) both in the observations and in the model. However, the ENSO signature over the region for distinct events varies substantially. Winter rainfall appears to be weakly influenced by ENSO. The high intra-seasonal and intra-regional variability of winter rainfall also confirms the weak ENSO signal and the chaotic nature of rainfall in the region.

WAVE PACKETS OBSERVATIONS IN THE EARTH'S CUSP REGION, AT THE MAGNETOPAUSE, AND INSIDE OF THE PLASMA SHEET BY THE MEASUREMENTS ON BOARD OF INTERBALL-TAIL PROBE.

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A new method of the wave analysis based on the idea of two types of the vector variables correlative dependencies ('scalar' and 'vector' ones) have been developed and applied to the magnetic field data obtained on board of the INTERBALL-1 satellite. This method allows to do the efficient spectral analysis of vector variables and rapidly find the wave vectors angular distribution and polarization states of the electromagnetic and magneto-hydrodynamic plasma waves. The low frequency wave properties was studied in the three different regions of the magnetosphere: in the high-latitude cusp region, at the magnetopause, and in the plasma sheet, during the higher level of wave activity (partially bounding with substorms). The discrete wave packets are characteristic for the low frequency variations in all these regions. Various events differ one from another by the wave mode composition. The ion-cyclotron wave packets corresponding to various ionosphere ion species are found in the high altitude cusp region and in the tail plasma sheet. In contrast, the spectra composed completely from packets of the linearly polarized compression mirror waves were observed nearby the high latitude magnetopause in time of the strong magnetosphere compression under the blow of the high density plasma cloud coming from the Sun on January 11, 1997.

THE SOIL-PRECIPITATION FEEDBACK: A STUDY WITH A REGIONAL CLIMATE MODEL

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Monthlong integrations with a regional climate model are utilized to study the sensitivity of the summertime European precipitation climate with respect to the ambient soil moisture content. Experiments are conducted for July 1990 and 1993. For each of the two months, the control experiment is compared against two sensitivity experiments with dry and wet initial soil moisture distributions. These experiments yield pronounced differences in the precipitation climate, and suggest that the location of the boundary between the wet Atlantic climate to the north, and the dry Mediterranean climate to the south, is heavily affected by the continental-scale initial soil moisture content. The investigation of the mean daily cycle throughout the integration period demonstrates that the physical mechanism underlying the soil-precipitation feedback is related to the development of the diurnal boundary layer and its interaction with soil, boundary layer, radiative and convective processes. Over moist soils, these processes act in concert to yield higher values of the moist entropy in the early afternoon boundary layer, and thereby to increase the potential for convective activity. The results suggest that soil moisture is a major factor affecting the summertime European precipitation climate, with implications for the seasonal cycle and the interannual variability.

INTRASEASONAL VARIABILITY OF THE INDIAN MONSOON

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The intraseasonal variability of the Indian Monsoon can be thought of as alternating active and break periods associated with two distinct preferred locations of the tropical convergence zone (TCZ), over the Indian sub-continent and over the equatorial oceanic region. Using the ECMWF re-analysis (ERA) data set for 1979-1993 a "climatology" of the active and break regimes has been produced. This has been done by spatially averaging daily precipitation data over two regions associated with the two preferred locations of the TCZ. Using these daily spatial averages, active and break periods have been identified and their composite structures examined. It is found that active and break periods have significantly different flow regimes associated with them over a large region in both the upper and lower troposphere. The different diabatic heating stuctures associated with the two regimes have been used to drive a simple numerical model and the resulting structures compared with the "climatology". The next stage is to run the model with the proportion of active and break heating determined by the flow itself.

ON THE PREDICTABILITY OF INTERANNUAL VARIATIONS IN THE ACTIVITY OF THE MADDEN JULIAN OSCILLATION.

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The Madden-Julian Oscillation (MJO) is the dominant mode of tropical variability at intraseasonal timescales. It displays substantial interannual variability in intensity which may have important implications for the predictability of the coupled system. Using the NCEP 40-year Reanalysis and the results from a 4-member ensemble of 45 year integrations with the Hadley Centre climate model, forced by observed SSTs for 1949-94, the relationship between MJO activity and SST has been investigated. The implications of the results for the predictability of the tropical ocean-atmosphere system will be discussed.

NUMERICAL STUDY OF THE IMPACT OF FIRST EIGENMODES OF SST VARIABILITY ON TROPICAL RAINFALL

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The 4 first EOF of Sea Surface Temperature Anomalies (SSTA) are sufficient to document main spatial structures of SST variability known to influence tropical rainfall. Each of these spatial structures is concerned with privileged time-scales. Thus linear combinations of these modes allow the construction of idealised SSTA patterns involving different time-scales. Numerical experiments performed with the AGCM ARPEGE-Climat (CNRM, Météo-France) using these patterns enable to investigate SSTA-related changes in rainfall and atmospherical circulation in the Tropics. The relative impact of ENSO and decadal scale SST variability of the global ocean as well as the meridional gradient of SSTA in Tropical Atlantic are investigated. Special focus is made on three areas of interest : Nordeste, Southern Africa and Sahel.

A CLIMATOLOGY OF ONSET DATES OF THE ASIAN SUMMER MONSOON

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Synoptic and intraseasonal variability lead to variations of the onset date of the Asian summer monsoon, and blur the predictability of this and other vital events like active/break phases. An objective method is used to find local onset dates and break days from daily precipitation and 850 hPa winds of the ECMWF reanalysis and an AMIP-type simulation of the same resolution (T106). The method uses local July precipitation as a threshold to cope with the high spatial variability and the biases in both ERA and ECHAM precipitation. The onset date lines are found to be sensitive on two different criteria for precipitation (3 consecutive heavy rain days vs. five day running means). The high resolution model ECHAM4 simulates a very realistic low level jet over the Arabian Sea both in strength and timing. Still, the onset in central India occurs a week earlier than in the reanalysis. Whether this and other biases of monsoonal precipitation are due to the land surface scheme, the convective parameterization, or the lack of realistic air-sea interactions is unknown.

THE PACIFIC COLD TONGUE AND THE ENSO MODE IN A FULLY COUPLED ZEBIAK-CANE MODEL

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The equatorial Tropical Pacific Climate system is a delicate coupled system in which winds driven by gradients of sea surface temperature (SST) within the basin interact with the ocean circulation to maintain SST gradients. This results in a time-mean state having a strong zonal temperature contrast along the equator with an eastern cold tongue and a western warm pool. By the same coupled processes also interannual variability, known as El-Niño/Southern Oscillation, is present in the Pacific. This variability can be attributed to an oscillatory coupled mode, the ENSO mode, in the equatorial ocean/atmosphere system. When the amount of windstress per SST, i.e. the coupling strength between the ocean and atmosphere, is changed this affects both the annual mean state and the ENSO mode. Using a Cane-Zebiak type intermediate coupled model, these linked features of the Pacific Climate are unified into one framework. The ENSO mode arises as a robust oscillatory mode on a coupled mean state and becomes unstable at sufficiently large coupling strength. The origin of this mode, its propagation mechanism, its relation to the spatial structure of the annual mean state and the interaction between the ENSO-mode and the seasonal cycle are considered.

WESTERLY WIND BURSTS AND TRIGERING OF ENSO.

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The westerly wind bursts are thought to play a key role in ENSO variability. They often result in oceanic Kelvin waves which propagate toward the eastern part of the basin and raise the thermocline toward the sea surface. In this study, we concentrate more on their impact in the western and central Pacific. Analytic westerly wind stress anomalies are introduced at the air - sea interface of a coupled general circulation model. Their local effect is to increase the oceanic turbulence, and to destroy the salinity "barrier layer". The easterly surface currents anomaly results in a significant eastward shift of the western Pacific warm and fresh pool, which is associated with the formation of a thick barrier layer in the central Pacific. This situation might favour the growth of a coupled ocean - atmosphere instability.

THE IMPLEMENTATION OF A NONLOCAL DIFFUSION MODEL IN THE HOPE OGCM

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A nonlocal diffusion model, Large et al (1994), is implemented in the Hamburg Ocean Primitive Equation model (HOPE) to establish an improvement in the simulation of mixed-layer dynamics in OGCMs. Preliminary results show that, as compared to the the original mixed-layer parametrization of HOPE, differences are found in equatorial regions. The existence of barrier layers becomes apparent in the warm pool region of the West Pacific. Also a change in magnitude and location of the equatorial currents is found. Finally a change in the density structure has an effect on the velocity of baroclinic equatorial waves. In the near future the performance of the nonlocal diffusion model will be evaluated against a bulk mixed-layer model and the results will be compared to data from observations.

INFLUENCE OF NAO INDEX TO SYNOPTIC WEATHER SITUATION OVER SWITZERLAND

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Fifty years of daily synoptic weather situations over the central part of the Alps are considered. The Alpine region is a transition zone between the Atlantic weather regime, a continental regime and the regime of the Mediterranean Sea and, therefore, sensitive to changes in the large scale weather pattern. To characterize weather systems over Switzerland, Schüepp has defined synoptic weather types adapted to the Alpine region. Although these weather types are manually determined by observers, they are defined by strict rules. Surface pressure and 500-hPa level maps of every day are used to derive parameters identifying Schüepp's weather types. Since the beginning of their records in 1945 pronounced changes in the annual frequency of the weather types could be observed. It is analyzed how these changes might be related to changes in the North Atlantic Oscillation (NAO) index. In winter there is a strong relation between the NAO index and the frequency of so-called high pressure situations. In summer the pressure pattern over the Atlantic influences the regional scale weather type to a much lesser extent.

TRACKING DOWN THE CAUSES OF THE 1997 EL NIÑO WITH AN ADJOINT OGCM

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The adjoint of the ocean general circulation model HOPE is used as a tool for investigating the causes of the 1997 El Niño. The adjoint computes the derivatives of the NINO3 index N_3 to the forcing fields $\mathcal{F}(t)$ used by the ocean model (wind stress, heat and moisture) and the initial state X_0 (temperature, sea level, salinity and currents). Adjoint Kelvin and Rossby waves can be identified in the sensitivities to sea level and wind stress at earlier times, which can be traced back for more than a year through western and weak eastern boundary reflections. The sensitivities to the heat flux and SST are local and decay in about a month.

Approximating the observed anomalies as small deviations from climatology, $N_3(T) \approx \partial N_3/\partial X_0 \cdot \delta X_0 + \sum_{t=0}^{T-1} \partial N_3/\partial \mathcal{F}(t) \cdot \delta \mathcal{F}(t)$, we can decompose the rise in the NINO3 index in the model during late spring 1997 into contributions from the various westerly windbursts (ECMWF wind stresses in December/January, March and April), other fluxes, and the preconditioning of the ocean at the beginning of December 1996 (ECMWF analysis).

DECADAL ANOMALIES OF THE ANNUAL CYCLE IN SST AND SLP FIELDS IN THE NORTH ATLANTIC

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Based on the National Centers for Environmental Prediction (NCEP) data set and the Comprehensive Ocean-Atmosphere Data Set (COADS) analysis of the interdecadal changes of amplitudes and phases of annual cycle in sea level pressure (SLP) and sea surface temperature (SST) fields is carried out. Anomalies of the above mentioned characteristics are estimated for four decades (1951-1990). Spatial distribution of the anomalies of amlitudes of SLP is in agreement with that of the anomalies of decadal mean SLP and positive (negative) anomalies of amplitudes are related to negative (positive) anomalies of decadal mean SLP. During 1951-1960 and 1971-1980 anomalies of phases are not great (approximately 10 days). But decades with the lowest (1961-1970) and highest (1981-1990) values of the North Atlantic Oscillation Index demonstrated the great growth of phase anomalies and their spatial differentiation. Positive (negative) anomalies of phases mean here that, for instance, winter comes later (earlier) than usual. During 1961-1970 the negative phase anomaly (-15 days) is located in the western Atlantic and the positive one (+35 days) near North Africa. During 1981-1990 the situation is reversed - positive (+25 days) anomaly in the western Atlantic, and the negative (-50 days) one near North Africa. Positive (negative) anomalies of amplitudes of SST are associated with negative (positive) anomalies of annual and winter means. Analysis of anomalies of phases of SST have not revealed significant interdecadal changes.

OA17 Climate variability: models and observations (co-sponsored by SE)

04 Clouds in the climate system: observations and modelling

Convener: Desbois, M.

CLOUD FIELDS DYNAMICS ABOVE THE CRIMEA

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The investigation is based on a large set of experimental data collected in expeditions in period from 1955 to 1978. Stereophotogrammetric measurements of the main parameters of clouds (such as top and bottom altitudes, rates of horisontal and vertical growth, scales, etc.) provided 1.5% — 3.5% approximation, depending on the type of clouds. During summer expeditions the measurements were made with time intervals from 1 to 30 minutes. A strong dependence of cloud dynamics on the winds direction was discovered. Thus, North-West currents perpendicular to the mountain chain generate wave orographic cloud fields which propagate from the mountain chain to the sea direction for 30 km. Besides, at the coast zone cumulus clouds are strongly influenced by these orographic phenomena while above the sea the clouds become more rarified. This feature explains the difference between the radiational regimes of the open sea and the coast zone.

VALIDATION OF CLOUD SYSTEMS IN THE GENERAL CIRCULATION MODEL ECHAM4 BY USING THE NUDGING TECHNIQUE

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Clouds are an important regulator of the Earth's radiation budget and present a major link between radiation and the hydrological cycle. We use a different approach to validate clouds in ECHAM4 T106 and investigate the representation of synoptic scale systems in 3 hourly stored data. The aim is to investigate, whether the realistic mean cloud amounts produced by the model are associated with a realistic representation of clouds in a higher temporal resolution. To do this we use the Newtonian relaxation technique (Nudging), which relaxes the model state towards reanalysis data by adding a non physical relaxation term to the model equations.

We present the representation of an extratropical cyclone. Vorticity, divergence temperature and surface pressure are nudged with ECMWF reanalysis fields. The main characteristics of the cyclone are well reproduced by the model. This is true even for variables which are not relaxed. As an example strong cloud cover occurs in frontal and central regions of the surface low and in the upper troposphere the cloud deck is shifted to pre-frontal regions. The investigation shows that the nudging technique is a useful tool for model validation, since model parameterizations can be tested by comparing with distinct observed synoptic situations.

A new parameterization of Cloud Properties and comparison of simulated and measured HIRS cloudy radiances

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Accurate modeling of the effects of clouds on absorption, transmission and reflection of thermal energy is crucial. The need for an accurate representation of infrared absorption by clouds is acute since the current uncertainty in this quantity has important consequences on the atmospheric radiation budget. Since the clouds strongly modulate the longwave radiation at the top of the atmosphere, they should be considered as the principal unknown parameter to be inferred in satellite cloud studies. Unfortunately, the exact evaluation of cloud effects require a long calculation time. So, in the spherical particles approximation, the Mie theory was used to develop a new parameterization of cloud optical properties. The scattered and forward trasmissivity and the scattered reflectivity are separately studied and the cloud emissivity is calculated under the energy conservation low. The parameterization is used to compute the cloudy radiances in HIRS/2 channels using the temperature, mixing ratio, liquid and ice content and cloudy fraction profiles obtained from ECMWF. Then cloudy radiances are compared to the one computed using the operational ECMWF emissivity formulation and to actually observed raw TOVS radiances.

COMPARISONS OF MODEL GENERATED FLUXES WITH SATELLITE INFERRED FLUXES

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For May 1993 and June 1993 radiation budget components at top of atmosphere and at surface were inferred from NOAA-AVHRR and Meteosat data. For the same time period model calculations with the regional model (REMO) were carried out to investigate the energy and hydrological cycle. The investigated area covers the watershed of the Baltic Sea (defined in the BALTEX programme), approx. an area of 1800 x 3000 km^2 with a resolution of 15 x 15 km^2.

To calculate the radiation budget components at surface from remotely sensed data, a complex analysis scheme could be applied, where cloud types as well as their optical properties could also be derived. Before a detailled comparison between satellite inferred results, like fluxes at TOA and at surface or cloud cover, with modelled results could be carried out, the satellite fluxes could be validated with surface observations in advance. This allows to define the achieved accuracies. Based on the different satellite data (NOAA AVHRR - two obs. per day, but high spatial resolution; Meteosat - half hourly resolution, but poor spatial resolution) different intercomparisons will presented.

SIMULATION OF MARINE STRATOCUMULUS EVOLUTION OBSERVED DURING ASTEX: COMPARISON WITH OBSERVATIONS AND SENSITIVITY STUDIES.

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In the "First Lagrangian" of the Atlantic Stratocumulus EXperiment (ASTEX), an air mass was followed for two days while it was advected by the mean wind toward warmer sea surface temperatures . Here, we simulate part of this evolution using the 1-D version of the hydrostatic primitive equation model MAR (Modèle Atmosphérique Régional) developed at the UCL. It includes a high-order turbulence closure, a wide-band formulation of the radiative tansfer and a parameterized microphysics including prognostic equations for water vapor, cloud droplets and rain drops concentrations. Partial condensation is allowed. A 24h simulation is carried out and the results are compared with in-situ measurements of the mean structure as well as the microphysical and turbulent structures. The simulation is sensitive to some external forcings like large-scale subsidence or sea-surface temperature, but also to sub-grid scale process parameterizations, like condensation and precipitation. Several sensitivity experiments will be presented. A particular attention will be given to the impact on surface energy fluxes since these are crucial in coupled ocean-atmosphere models.

COMPARISON OF ISCCP C1 AND D1 CLOUD DATASETS

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The importance of clouds in climate has long been recognised and long-term observations are needed to monitor changes in cloud fraction and cloud properties. The ISCCP project provides information on the space-time characteristics of clouds, such as cloud amount, cloud top pressure, and cloud optical depth. These characteristics inferred from the visible and infrared radiances measured by radiometers on various satellites allow clouds to be classified into cloud types. It is expected that the C1 cloud product will progressively be replaced by the improved D1 cloud product. The purpose of this presentation is to point out some resemblances and differences between the C1 and D1 datasets.

CONVECTIVE MESO-SCALE BOUNDARY LAYER CLOUDS STRUCTURES DURING THE SEMAPHORE CAMPAIGN.

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One of the objectives of the SEMAPHORE campaign is the concern of Ocean-Atmospheric fluxes with the convective activity within the planetary boundary layer. The convective activity is determined from its cloud signature - closed and opened cells, cloud streets - in the AVHRR views of the SEMAPHORE region.
As a first step the cloud classification of Seze-Desbois allows to segregate between low clouds fields and others; moreover, it allows to characterize the cell fields through a bench of specific classes. The second step consists in an algorithmic treatment of the classification output to specify the shape, extension and arrangement of the cells within the low clouds fields. As a consequent, the variability and irregularity of the geometric characteristics of the clouds - which are at the origin of the choice of this method - are thus quantitatively restituted. Finally, the geometric information is used to extract the physical characteristics of each determined elementary object from both the classification outputs and the four-channel AVHRR data. Tus, the charactristics of a mean elementary cell or roll is given which allows future comparison with model outputs.

BOMEX 1D INTERCOMPARISON: IMPACT OF THE PARAMETRIZATION OF THE SHALLOW CONVECTION ON THE SURFACE FLUXES

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For the "Air-Sea-Ice Interactions" project, simulations of a case from the phase III of the Bomex campaign have been performed. This is a non-precipitating cumulus maritime case. Stationnarized results from the Cloud Resolving Model (CRM) have been used to initialize 1D versions of AGCMs. The participating groups in the intercomparison and the corresponding models were the KNMI (Holland) with a CRM, ECHAM3 and ECHAM4; the LMD (France) with LMD5; the DMI (Denmark); the University of Reading (UK) with the UGCM and the CNRM (France) with Arpège-Climat.
In the Arpège-Climat simulation, the mixing layer is too thick, the BL is too warm and too dry; hence sensible heat fluxes and latent heat fluxes at the surface are not realistic. Moreover, strong temporal oscillations with a $4\Delta T$ period in the surface latent and sensible heat fluxes are generated. The parametrization of the shallow convection is the main source of the errors. The shallow convection is parametrized as a modified Richardson number: an additional term depending on the vertical gradient of the distance to the saturation (term in $L\partial(q - q_{sat})/\partial z$). The absolute value of $\partial\theta/\partial z$ is much smaller than the absolute value of the additional term. Two simple solutions to improve the simulations have been proposed and tested.
A change in the physical parametrizations (use of a statistical cloud scheme) substantially improves the simulation. Both the effects of the liquid water in the vertical diffusion scheme and the parametrization of the direct interactions between the turbulence, the radiation (optical properties of the cloud) and the diabatic processes (condensation/precipitation) are found necessary for a good simulation of the BL.

NANOPARTICLE FORMATION EVENTS AT A BOREAL FOREST SITE

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Number size distribution of submicron and ultrafine aerosol particles have been measured on a continuous basis (every 10 minutes) at a forest site in Southern Finland. Very often, only Aitken (40-100 nm) and accumulation modes (150-200nm) are present. In several sunny days, the appearing nucleation mode (peak at 5-6 nm) can be seen to increase both in size and concentration. During the day the growth rate for the nucleation mode is in the order of few nm/hour and at late evening the nucleation mode merges into the Aitken mode. Simultaneous eddy covariance measurements have revealed upward particle fluxes, when there is formation of new particles. Atmospheric significance of observations are discussed.

OA17

STUDIES OF UPPER TROPOSPHERIC HUMIDITY USING AIRBORNE IN-SITU SENSORS

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Upper tropospheric water vapour is widely recognised to be of fundamental importance in regulating the earth's climate, despite its low concentrations, because it is a dominant term in the outgoing longwave radiation that cools the planet. Nevertheless, the knowledge of UTH distribution is very limited. This paper presents an on-going study of the performance and measurements of the Fluorescence Water Vapour Sensor, onboard the British C-130 Hercules research aircraft. Our investigations have indicated the necessity of laboratory tests in order to develop a deeper understanding of the instrument's response. These investigations and preliminary results of the tests are shown. Finally, case-study comparisons between the FWVS and the airborne frost-point hygrometer data along with satellite and re-analysis data are presented and the discrepancies are discussed.

CLOUD MICROPHYSICAL AND RADIATIVE PROPERTIES}

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The boundary layer clouds, covering extensive areas of our globe, have a significant impact on the Earth's radiative balance and thus on climate. Parametrization of cloud radiative properties as a function of their microphysical characteristics are needed for retrieval of cloud microphysical parameters from remote sensing measurements and for simulations of aerosol indirect effect (modification of cloud albedo) in GCMs. Usually layer clouds are represented as plan parallel homogeneous horizontally and vertically and their radiative properties are defined by two parameters: optical thickness and effective radius. In reality such clouds are not homogeneous neither horizontally not vertically. In the scale of a convective cell the vertical adiabatic profiles are well documented by in-situ measurements, so it is possible to describe recisely the cloud microphysics and radiative properties by using only two parameters: cloud depth and droplets concentration (what allows to easily describe the indirect effect of aerosols). This result is then averaged in order to get the mean radiative properties of the cloud system. EUCREX (European Cloud Radiation Experiment) and ACE2 (Aerosol Characterization Experiment) were dedicated to in-situ studies of microphysical properties of marine stratocumuli and simultaneous measurements of their radiative properties. The results of these experiments will be presented.

Cloud type and horizontal variability in marine boundary layers

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Large scale models such as those used for weather prediction and simulations of climate change typically estimate the radiative effects of clouds based on the cloud fraction and total amount of condensate within each grid box. It is known, however, that the assumption that cloud optical properties are horizontally uniform leads to a systematic bias towards larger albedo and smaller absorption. Simple techniques have been developed to account for cloud spatial inhomogeneity in radiation calculations, but observations of this variability are quite sparse.

We use simultaneous co-located observations by ship observers and satellite radiometers to characterize the variability of marine boundary clouds. We examine the sensitivity of cloud detection by satellite instruments to cloud morphological type as reported by the ship observers and to sensor spatial resolution. Observed distributions of cloud optical thickness are well described in most cases by several two-parameter models including log-normal and gamma distributions. The resultant bias in domain averaged albedo over the spatial scales used in current models is relatively small, but it can be nearly eliminated using one of the simple models of variability. The parameters which characterize the distributions are dependent on cloud type, most importantly on whether the clouds are reported as isolated (cumuliform) or nearly continuous (stratiform).

Cloud cover observed simultaneously from POLDER and METEOSAT

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The POLDER instrument that was aboard the Japanese ADEOS platform between August 1996 and June 1997, is designed to the global observation of the polarization and directionality of the sun-light reflected by the earth atmosphere system. The cloud detection from POLDER takes advantage of the original capabilities of the instrument (spectral polarization and directionality). This cloud scheme uses 5 threshold tests based on pressure, reflectance, polarized reflectance, spectral variability. The results of the POLDER cloud detection scheme are compared to those of the LMD dynamical clustering method applied to visible and infrared METEOSAT data and local spatial variability of these two parameters. Special focus is given to the detection capabilities of the two kind of measurements for cloud situations such as small cumulus, thin cirrus and multi-layered cloud cover. Results of this comparison will give some insight on the behavior of the International Satellite Cloud Climatology (ISCCP) scheme built mainly from visible and infrared measurements.

DIRECT EVIDENCE FOR CLOUD CASCADE DYNAMICS FROM PLANTARY SCALES TO 1KM

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We analyzed over a thousand visible and infra red images from geostationary (GMS), polar orbiting (NOAA 12, 14, SPOT) satellites as well as ground based images (roughly 100 times more data than that used on any comparable study) to study the scaling properties of clouds over the range 5000km to ≈50cm. As predicted by the unified scaling model, the radiances are accurately multiscaling over the entire range and we estimate the corresponding (universal) multifractal exponent functions. Although the individual images involve factors of only ≈1000 in scale (compared to the range of over a billion from the planetary scale to the dissipation scale), these large (climatological scale) data sets enabled us to obtain the first direct estimates of the outer scale of the underlying (multiplicative) cascade process. Both the GMS (over the Pacific) and AVHRR (over Oklahoma) data yield estimates of the order of ten thousand kilometers; an agreement which is particularly convincing in this regard.

We discuss the significance of these results for radiation, climate and modelling.

TIMESCALES OF VARIABILITY IN TROPICAL RADIATIVE-CONVECTIVE EQUILIBRIUM

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In an undisturbed environment, the tropical atmosphere tends towards a state of radiative-convective equilibrium. The timescale on which this balance is achieved is an important issue. This convective heating and moistening response has been previously suggested, for example, as central to amplification of large-scale wave-motions, and their successful simulation in global models.

To examine internal convective variability, we have integrated a three-dimensional cloud-resolving model with an interactive radiation scheme to a state of radiative-convective equilibrium. Using a model that explicitly resolves convection avoids the timescales assumptions built into parameterizations schemes, but does not allow the two-way interaction between convection and large-scale wave motions to be studied due to the limited domain size.

It is found that the approach to equilibrium can be divided cleanly by a process separation into two timescales; a long 20 day exponential trend to equilibrium superimposed by short timescale variability that is almost solely associated with convective activity. Of the two possible mechanisms of surface fluxes and radiation it is found that the latter determines the long-timescale adjustment.

A SENSITIVITY STUDY OF RADIATIVE-CONVECTIVE EQUILIBRIUM IN THE TROPICS WITH A CONVECTION-RESOLVING MODEL

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Statistical-equilibrium (S-E) states of radiative-convective systems in tropical oceanic conditions are simulated with a cloud ensemble model (CEM) in this study. Typical large-scale conditions from the Marshall Islands and the eastern tropical Atlantic regions are used to drive the CEM.

The simulated statistical-equilibrium precipitable water, column temperature and relative humidity profile are almost identical to the observed for both regions when observed, time-invariant large-scale advective cooling and moistening effects are imposed. They are higher than the observed if observed, time-invariant large-scale ascent is imposed for the Marshall Islands region (i.e., ignoring horizontal advective effects). Compared with results from two similar studies, the simulated S-E state from this study is somewhere between the cold/dry regime by Sui et al. and the warm/humid regime by Grabowski et al. Temporal variations of the imposed large-scale vertical motion make the simulated S-E state slightly colder and drier. It remains about the same, however, if the magnitude of the imposed large-scale vertical motion is halved. The S-E state is much colder and drier if the large-scale ascent is zero or if solar radiation is absent. In general, the results show that wet column are thermally stable and dry columns are thermally unstable.

Column budget analyses are performed to explore the differences among the simulations performed in this study and among the different studies.

OA17 Climate variability: models and observations (co-sponsored by SE)

05 Prediction and detection of anthropogenic climate change

Convener: Johns, T.C.

GCM CLIMATE CHANGE SCENARIOS FOR BULGARIA

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Climate change scenarios for Bulgaria using global circulation model (GCM) outputs were derived and analyzed. The GCMs used in the study are those from the Canadian Climatic Center (CCC), Goddard Institute for Space Studies (GISS), Oregon State University (OSU), Geophysical Fluid Dynamics Laboratory (GFDL R-30), United Kingdom Meteorological Office (UK89) and Hadley Centre in the United Kingdom (HCGG and HCGS which integrates the negative forcing effect from sulfate aerosols. The GCM simulations regarding the current climate were compared to the averaged database of the observed climate. The GCMs do not perfectly simulate the present climate in Bulgaria. Nevertheless, the 1xCO_2 OSU, HCGG and HCGS outputs are in a relatively good agreement with baseline air temperature from June to March. They could be considered as the most appropriate global circulation models for monthly air temperature in Bulgaria (except April and May) among the GCMs used in the study. According to the 2xCO_2 GCM outputs used in the study annual temperatures in Bulgaria are projected to rise between 2.9° (HCGS) and 5.8°C (UKMO). Under the GFDL-T transient scenario in the 2000s, 2030s and 2060s annual temperatures are projected to increase by 1.2°, 2.2° and 3.9°C, respectively. In general, precipitation is expected to increase during the winter and to decrease during the warm half-year(CCC, GISS, GFDL R-30, OSU). The 2xCO_2 UK89 and HCGS models even project minor increasing only in November and July, respectively.

DETECTING EXTERNAL FORCINGS OF THE ATMOSPHERE USING THE ERA DATA SET

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The European Re-Analysis (ERA) data set provides not only re-analysed observations, but also short range forecasts based on these data. A forecasted field will, of course, deviate from the observed, re-analysed field. Assuming a realistic model and perfect observations, this deviation, also called analysis increment, may in most cases mainly be assigned to instrumental inhomogeneities and external forcings that are not considered by the forecast model. The contribution by instrumental inhomogeneities is assumed to be mainly on a time scale of years. Thus, the analysis increment will, particularly on shorter time scales, provide a measure of external forcings. This paper presents a study of analysis increments of temperature fields at several pressure levels.
Some external forcings such as the strong emissions of sulfate aerosols from the vulcanic eruptions of El Chichón (1982) and Pinatubo (1991) are easily identified, and serve as a good verification of this method. Particular attention is paid to possible forcings originating from solar activities. Both Forbush decreases which has a time scale of days and forcings on the longer time scale of the 10-12 year solar cycle, like the reported influence of cosmic ray flux on cloud cover, has been investigated. Though the results are less conclusive on the longer time scales, this study of temperature fields shows little evidence of forcings induced by such solar activities.

MEDITERRANEAN SEA: INCREASE IN GREENHOUSE EFFECT, AIR AND SEA TEMPERATURES AND FRESHWATER DEFICIT

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In the deep waters of the western basin, increasing trends of temperature and salinity, observed since the early 1960s (Bethoux and Gentili, 1996), may be simulated by surface evolutions of heat and water budgets across the sea surface, i.e. two concomitant driving forces. Over the 1940-1995 period, the estimated change in greenhouse effect simulating the warming trend reaches 1.74 Wm^{-2}, which is in agreement with the calculated change (GIE, 1995), and sea surface and air temperature increases amount to 0.4 and 0.5°C, respectively. Simulation of salinity trends requires an increase in water deficit of 0.10 m a^{-1} in 1995. This originates in:
i) decreases in Nile river outflow (after the closing of High Dam in 1954), and Ebro river outflow (human freshwater use); ii) increase in salty flow from the Red Sea (following the deepening and widening of the Suez canal); iii) decrease in precipitation over the Mediterranean; iv) increase in evaporation (feedback from the surface temperature increase). Causes are both from anthropogenic and climatic sources. Mediterranean sensitivity to climatic and environmental changes constitutes chances to monitor present changes, if climatic and socio-economic data exist.

Bethoux, J.P. and Gentili, B., 1996. J. of Mar.Systems, 7: 383- 394.
GIEC, 1995. Changements climatiques 1995. PNUE/OMN, pp. 64.

RESPONSE OF THE NCAR CLIMATE SYSTEM MODEL TO CHANGING GREENHOUSE GASES

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The NCAR Climate System Model (CSM) is a relatively new model of the physical climate system, including coupled atmosphere and ocean general circulation models, a dynamic sea ice model and a land surface model. This paper summarizes results of several CSM experiments in which the concentrations of greenhouse gases change with time. Trends are compared with the natural variability of a 300 year control simulation and with the observed record.
An idealized experiment, following the guidelines for CMIP2, in which CO_2 increased from present levels (355 ppmv) by 1%/year will be discussed. This experiment was run until the CO_2 concentration tripled (115 years) and is compared to a 300 year control simulation. In this experiment, the global mean surface temperature increases by $\sim$ 1.3 K at the time of CO_2 doubling (70 years). The equilibrium temperature increase for CO_2 doubling is $\sim$ 2 K, as determined by experiments with a 50 m slab ocean.
A more realistic series of experiments is currently underway, in which changes in the principal greenhouse gases (CO_2, O_3 CH_4, N_2O, CFC11, and CFC12) and sulphate aerosol from 1870–1990 are included. These experiments begin from an approximate equilibrium condition for 1870 and account for most of the greenhouse gas changes since pre-industrial times.

MAIN REGULARITIES OF THE CLIMATE CHANGES OF UKRAINE IN THE PAST

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The was made a critical analysis of materials concerning changes of land-surface temperature, intensity of atmospheric precipitation and statistics of catastrophic hydro-meteorological phenomena on the territory of Ukraine, obtained on the basis of resulis of meteorological paleo-reconstruction, historical (manuscript) records and instrumental hydro-meteorological observations. There were found general changes regularities of the climate of Ukraine during the last 10 000 years. There were considered conditions, in which the climatic fields of land-surface temperature and the intensity of precipitation, which took place in warm periods of the past, may be analogous for the development of scenarios of Ukrainian climate changes in the near future taking into account forecasted global warming being the result of the anthropogenic increase of the green-house gases effect.
The statistics of catastrophic hydro-meteorological processes (CHMP) is quantified by the well-known relation for Puasson flux of events. There were made estimates of the Puasson flux of CHMP on the territory of Ukraine and there was considered the possibility of their use for forecast of global warming influence on the statistics of CHMP on the territory of Ukraine in the near future.

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OA 17. Climate variability: models and observations. 05. Prediction and detection of anthropogenic climate change. Convener: T.C. Johns (Bracknell). poster

POSSIBLE CHANGES IN EL-NIÑO/SOUTHERN OSCILLATION IN A WARMER CLIMATE

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The El-Niño/Southern Oscillation (ENSO) is examined in the Hadley Centre climate model to asses any future changes in the behaviour of ENSO in a warmer climate. Various simulations, forced with transient increases in CO_2 alone, transient increases in CO_2 and sulphate aerosols, and simulations with equilibrium changes, are compared with a multi-century control run forced with present day CO_2 levels. ENSO indices from the model and from the observations are compared using spectral and wavelet analysis techniques. These measures of ENSO activity are tested for statistical significance against the control integration which is used to estimate a measure of the "natural" variability of ENSO. The preliminary indications are that power in the 2-3 year band of the NINO3 index increases in many of the increased CO_2 simulations. If the model predictions are correct, this implies that ENSOs will become more frequent in a warmer climate.

THE EFFECT OF UNCERTAINTIES IN RADIATIVE FORCING ON SURFACE TEMPERATURE TREND PREDICTIONS

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This paper examines the range of uncertainty in our knowledge of the anthropogenic and natural radiative forcings since 1850. Simple climate models and an Intermediate General Circulation Model (IGCM) are used to crudely examine the likely effect of these forcings on the surface temperature trend. It is concluded from these experiments that any agreement between time-dependent global-mean surface temperature trends and surface temperature trends from GCM runs, which include only a few of these forcings, are probably only fortuitous, and as such the evolution of surface temperature in these experiments to not constitute a "detection of anthropogenic climate change".

VARIATIONS IN HEMISPHERIC AIR-SURFACE TEMPERATURE ASSOCIATED WITH LARGE SCALE FLOW PATTERNS

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To what extent the recent upward trend in hemispheric mean surface air temperature should be purely ascribed to persistent circulation-related anomalies, is still an open question. The purpose of this study is to clarify the role played by the internal atmospheric variability in generating hemispheric mean surface air temperature anomalies. To investigate this problem an analysis is performed on a basis of monthly mean values from a 1000-years integration of the ECHAM1-LSG coupled model in which only the cold season was considered. In order to isolate important coupled modes of variability between time series of 500 hPa geopotential height and two metres temperature, a Canonical Correlation Analysis (CCA) was carried out. The two fields were prefiltered by retaining only the projection of each field on a (particular) subset of its Empirical Orthogonal Functions (EOFs) then applying CCA. This analysis has identified fairly distinct patterns associated with positive and negative trends of the hemispheric-mean surface air temperature. It is found that fluctuations in hemispheric-mean surface air temperature in the model are correlated with the strength of the North Atlantic Oscillation. The model results are then compared with the available observations.

REGIONAL IMPACTS OF THE VEGETATION FEEDBACKS IN DOUBLED-CO_2 CLIMATE EXPERIMENTS

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Three 10-year doubled CO_2 experiments have been performed with the ARPEGE atmospheric general circulation model of Météo-France in order to investigate how the CO_2 impact may be affected by possible vegetation feedbacks. Besides a first time-slice experiment with no modification of the vegetation properties, two other experiments have been performed in which changes in the plants' physiology (stomatal resistance) and structure (vertical density of the canopy) have been explored. On global and annual average, the vegetation feedbacks do not much modify the model's response to the CO_2 doubling. On the regional scale, the effect may be much more significant, which is demonstrated through the example of the Indian summer monsoon. Despite the increased land-sea temperature contrast, the monsoon circulation and precipitation are weaker in the first time-slice experiment, due to a competition between convection over the Indian continent and the Indian Ocean. This impact successively disappears and reappears when the physiological and structural feedbacks of the terrestrial vegetation are considered. This result shows the need for including more interactive land surface schemes in climate models, in order to capture all the processes involved in the carbon and water cycles.

QUANTIFYING THE UNCERTAINTIES DUE TO LAND-SURFACE SCHEMES IN CLIMATE CHANGE PREDICTION

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In their 1995 report, the IPCC identified land-surface processes as an area of large uncertainty in predictions of global and regional climate change due to greenhouse gases. The Land Surface Processes and Climate Response project, funded by the European Union, is an attempt to determine the magnitude of this uncertainty through collaboration between modelling centres. In this work four atmospheric general circulation models were used to perform at least two pairs (control and anomaly) of climate simulations. The difference between each pair was a change in some aspect of the land-surface scheme used. The experiments were all time-slices of at least 10 years with the same, specified sea surface temperature and sea ice data. For several regions, statistically significant changes in regional climate can be picked out from model noise, and the differences and similarities across the land-surface schemes and GCMs analysed. For some regions and variables, results for the same GCM with changed land-surface parametrisation cluster together whereas in other regions the difference between land surface schemes equals that between GCMs. In the Amazon basin for example, the difference in climate response between land-surface schemes was similar to that between GCMs.

CIRCULATION MODES AND THEIR INTERDIURNAL VARIABILITY IN THE ECHAM GCM

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The contribution addresses two items: (i) validation of the ECHAM GCM in terms of circulation patterns and their interdiurnal variability, and (ii) potential changes in circulation regime in $2\times CO_2$ climate. Circulation is expressed as a linear combination of Principal Components (PCs) which represent leading modes of variability in 500 hPa geopotential height field. Geopotential data were available in three variants: (i) raw data, (ii) low-passed data (to filter out high-frequency variations) and (iii) band-passed data (to retain synoptic-time-scale variations). PCs were derived separately for the 4 seasons of the year, from **a)** observed data, **b)** GCM (ECHAM3/T42) control run (present climate), and **c)** GCM/$2\times CO_2$ run. Comparison of circulation modes (spatial patterns of PC loadings) and their interdiurnal variability (represented by lag-1 correlations among PC scores) derived from individual data sets shows: (i) the circulation modes are well reproduced in GCM/control run, (ii) good correspondence between GCM/control and GCM/$2\times CO_2$ modes suggest only small changes in circulation regime over Europe due to doubled CO_2, (iii) the GCM/control circulation is more persistent (compared to observation) and closer to GCM/$2\times CO_2$ than to observation.

Changes in extreme daily precipitation predicted by general circulation models under scenarios of increased CO2 concentration

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A change in the intensity and distribution of daily precipitation towards more extreme events in certain areas is predicted by Hadley Centre general circulation models (GCMs) in greenhouse gas (GHG) emission scenarios. This shift could have significant consequences, resulting in floods, for instance, in some areas. In this study, changes in precipitation intensity are characterised by appeal to the probability density functions of daily precipitation amounts at each location, because it may be more instructive to define extreme events in terms of geographically dependent probabilities, rather than fixed value thresholds. We also compare the GCM results for changes in extreme events over Europe with corresponding results from a limited area model, the Hadley Centre Regional Climate Model.

CLIMATE CHANGE DUE TO A CO_2 INCREASE AS SIMULATED BY THE IPSL COUPLED MODEL

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The IPSL coupled model has been used for two eighty-year simulations: a control simulation with constant CO_2 concentration and a scenario simulation with a 1% yearly increase in CO_2 concentration. The absence of any flux corrections implies that an initial drift, which stays reasonable, is present in the two simulations. The general characteristics of the control simulation will be presented as well as the perturbations on the atmospheric and oceanic circulations due to the CO_2 increase and particularly the SST perturbation which is peculiarly strong along the equator in the Pacific. Comparisons with similar experiments using a simple oceanic mixed layer as the oceanic component of the coupled model will be made to illustrate the part of oceanic circulation in the perturbed simulations.

A STUDY FOR THE IDENTIFICATION OF CO_2 SOURCE AREAS.

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We present a study concerning the distribution of CO_2 atmospheric concentration and its possible sources on synoptic scale. The used method is the following:

a) we have measured the continuous concentration of CO_2 concentration at the alpine station of Plateau Rosa

b) we have calculated backwards trajectories of air crossing the monitoring station every 6 hours. For the trajectory calculation we have used the wind speed fields provided by the ECMWF objective analysis.

c) we have calculated the medium field of CO_2 concentration on European area following what was suggested by A. Stohl (Trajectory Statistics-A new method to establish source-receptor relationships of air pollutants and its application to the transport of particulate sulfate in Europe, Atmospheric Environment, vol.30, n.4, 1996)

The described procedure is applied to the data period April 1993- March 1995.

The results are presented and discussed.

SIGNIFICANCE OF ROOTING DEPTH ON CLIMATE CHANGE PREDICTION

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The IPCC report predicts increased summer drying in the Northern Hemisphere in an enhanced greenhouse climate. This of major significance as it affects a major agricultural belt as well as many other land areas. One factor determining the vegetation stress is the total water availability, which is closely related to the rooting depth. However there is currently limited biome rooting depth data available and it is generally not directly applicable to GCMs.

As part of the *Land Surface Processes and Climate Response* collaborative project, the ECMWF's (European Centre for Medium-Range Weather Forecasts) IFS GCM (version 15r1) is used to carry out a number of $2xCO_2$ simulations. The SST fields are prescribed and based on climatology, with adjustments made for $2xCO_2$ conditions. Experiments are performed with a range of globally uniform rooting depths which are chosen to cover most of the observed variation. Finally a geographically varying rooting depth field is developed and tested. The importance of rooting depth is assessed, both in terms of the accuracy of the present day simulation and on its effect on climate change sensitivity.

THE INFLUENCE OF GLOBAL WARMING ON THE LEVEL OF THE BLACK AND AZOV SEAS

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There was made the statistical analysis of instrumental measurements of Black and Azov seas' levels during the last 100 years. The results were compared with the instrumental data on the state of land-surface temperature of the North Hemisphere and also with the own increase of the World Ocean level. All numbers are well correlating (correlation coefficients, for example, between the changes of average temperature and the level of the Black sea is 0,57, and between the changes of the levels of the Black and Azov seas – 0,72) and have the tendencies to increase on the background of low-frequency fluctuations, which is the evidence of the influence of global warming on the level of not only the World Ocean as a whole but also internal seas. It was found that Black and Azov seas are reacting quickly enough on the temperature changes and can, in some sense, be climate indicators. The results were used for forecasting the changes of the level of the Black and Azov seas in the near future.

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NONPARAMETRIC TEST OF AR ORDER WITH APPLICATION TO THE GCM-SIMULATED AND MEASURED AIR TEMPERATURES

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Estimate of the impacts of climate change on agriculture, water resource management etc. requires high resolution (in space and time) air temperature data. Since the output from general circulation models (GCMs) is frequently unreliable at the local scale, alternative method to obtain such data is to use a stochastic weather generator, which employs an autoregressive model to simulate the daily extreme air temperatures. New nonparametric tests of the order of the autoregression in the time series, based on autoregression rank scores, were recently developed by Hallin and Jureckova, 1997. These tests and order identification procedure will be applied to a 30 years dataset of daily extreme temperatures in south Moravia (Czech Republic) over the period of 1961-1990 and to daily temperature series simulated by GCMs for $1xCO_2$ and $2xCO_2$ climate.

ON THE ENERGY RELATED CLIMATE VARIABILITY

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The importance of interaction between climate as one of the main natural systems and energy as a major sector in the economy defines the necessity to study this interaction in deep. The paper presents results from such a study focused on the energy related climate variability. The study aims to describe and quantify relations between the energy related Greenhouse Gas emissions, CO2 and NOx in particular, and some basic climatic characteristics like average temperatures at regional scale. The analysis within the study is performed in the framework of the concept for the differences between the global and regional pattern of the climate system behaviour. On the other hand, predictions for the future state of this system are mostly necessary at regional scale for the development of relevant energy policy for a country or region. The study provides basis to formulate principles for the development of such a policy in order to support decision-makers.

WHETHER THE GLOBAL WARMING CAN BE AVOIDED ACCORDING TO THE "IRON THEORY" OF DR. J. MARTIN?

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On the basis of the data obtained by instrumental measurements carried out by our research group in the open sea and laboratory it was shown that it is impossible to stop warming of the climate as predicted by the "iron theory" of Dr. J. Martin. The idea was that phytoplankton in the ocean needs iron and if the ocean were "fertilized" with iron compounds, the growth rate and abundance of phytoplankton would increase. This would lead to fixing CO_2 dissolved in sea water in the process of photosynthesis and, consequently, to reduction of air emissions of CO_2. In the course of the experiment a 65-km^2 patch of the equatorial Pacific 1600 km west of Ecuador coast was fertilized by sprinkling 450 kg of iron sulfate from a ship. This yielded 500 ton of phytoplankton and the emission of carbon dioxide from the ocean was reduced by 60%. Thus, it seemed that the experimental results fully confirmed the "iron theory" and provided a way to reduce the greenhouse effect.

However, the results of the "iron theory" should be treated with caution due to the fact that the experiment did not take into consideration other possible processes which accompany induced growth of phytoplankton. Incidentally, growth of biomass in the ocean would undoubtedly cause clouding of sea water and, hence, transformation of the absorbed solar radiation into heat. As a result the emission of water vapor into the atmosphere, increases, which leads to enhancement of the greenhouse effect.

Sea Level Rise: HadCM2 Model Predictions

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Observations indicate that the global mean sea level has risen at a rate of approximately 1.8 mm yrl during the past century. Furthermore, modelling studies suggest that increased atmospheric concentrations of greenhouse gases will result in an increased rate of sea level rise in the future. In this work, both the global mean and the spatial pattern of sea level rise predicted by the HadCM2 model are presented. The spatial pattern of sea level rise is shown to be spatially inhomogeneous with a range that is of the same order of magnitude as the global mean sea level rise associated with thermal expansion. The pattern of sea level rise determined from the change in the model's inferred sea surface height is compared with the patterns of: heat uptake by the ocean, thermal expansion deduced from changes in modelled ocean temperature structure, and changes in surface wind stress and atmospheric pressure. In addition, the depth and spatial variation of the terms in the Navier Stokes equation are considered in order to elucidate the changes in ocean circulation that are concomitant with the sea level rise.

TREND ESTIMATES FROM US ROCKETSONDE STATIONS AT LOW LATITUDES (8°S-34°N), TAKING INTO ACCOUNT INSTRUMENTAL CHANGES AND NATURAL VARIABILITY.

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Long-term changes of temperature and wind data obtained with US rocketsondes at 6 selected sites at Northern tropical and subtropical locations (from 8°S to 34°N) have been investigated. The analysis method used here is based on a multi-functions regression analysis that takes account for a continuous linear trend, for natural variability, as well as sudden change of the mean due to successive instrumental improvements. Changes in the time of measurement may also impact on trend estimates due to tidal effects. This effect is probably enhanced by the direct solar radiative heating on the sensor. Using this analysis, a significant cooling of 1 to 3 K/decade, increasing with height (20-60 km) is detected in the upper stratosphere. A similar analysis on zonal wind data reveals no significant trends larger than 0.5 m/s/year.

ESTIMATING CLIMATE TRENDS BY NONPARAMETRIC REGRESSION

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Trend analysis of climatological time series has an important role in description of climatic changes. A general model for time series $y_0, y_1, \ldots, y_n$, is $y_j = f(t_j) + e_j$, $j=0,1,\ldots,n$ where $f(t)$ is a deterministic function called trend function which has to be estimated and $\{e_j\}$ is a sequence of uncorrelated random variables with zero expectation. Knowing the analytical form of $f(t)$ the estimation is straightforward. Unfortunately, the typical case is that form is not known and therefore a model is chosen for $f(t)$. Nonparametric regression methods, which do not require the choice, represent estimators unbiased up to kth derivative of the trend function defined by a local kth order polynomial approximation of $f(t)$. The problem results in a weighted linear combination, i.e., smoothing of the observations $\{y_j\}$. The question is how to choose smoothing weights and range of smoothing (bandwidth). The presentation discusses these problems, as well as the advantage of locally varying bandwidth. Methodologies concerning the choice of bandwidth will be applied to a Northern Hemispheric temperature anomaly data set.

A TIME-SLICE EXPERIMENT WITH THE ECHAM4 A-GCM AT ENHANCED RESOLUTION: FIRST RESULTS

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A time-slice experiment has been performed employing the ECHAM4 A-GCM at a horizontal resolution of T106 with each time-slice covering a period of 30 years. The first time-slice represents the present day climate and the second one the climate at a time, when the CO_2 concentration in the atmosphere has doubled. In these time-slices the atmosphere has been forced by lower boundary files, that are monthly mean values of the sea surface temperatures, the sea-ice extent and the sea-ice thickness, obtained from a transient simulation with the ECHAM4/OPYC A-O-GCM at a horizontal resolution of T42, where the concentrations of the important greenhouse gases had been prescribed according to the IPCC scenario 1992a. We present results showing the anticipated change in the general circulation due to a doubling of the CO_2 concentration in the atmosphere as derived from these time-slices. This includes seasonal mean fields of various meteorological variables as well as variations on sub-seasonal timescales.

PERFORMANCE OF CURRENT CLIMATE-MIDDLE ATMOSPHERE MODELS: RESULTS FROM THE GRIPS INITIATIVE

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Current interest in the middle atmospheric effects on climate motivated the formation of the SPARC (Stratospheric Processes and their Role in Climate) project of the World Climate Research Programme. One initiative of SPARC is designed to assess the performance of current climate-middle atmosphere models; thirteen models are presently included, all of which include a full representation of the hydrological cycle and radiative processes and extend upwards to at least 1 hPa.
One of the first exercises of the GCM-Reality Intercomparison Project for SPARC (GRIPS) is an assessment of the models simulation of the current climate. This gives a background for planned sets of experiments, which will investigate how well the effects of middle atmospheric change on climate can be predicted.
The present paper will discuss results of GRIPS, first concentrating on the simulated structure in the lower stratosphere and upper troposphere. The importance of the reference climatology will be emphasised. The second focus of the presentation will be on the structure of the mean standing waves in the troposphere and stratosphere in the Northern Winter. These two issues have tremendous implications for current and future climate simulations.

TESTING FOR GLOBAL WARMING AGAINST STATIONARY NATURAL CLIMATE VARIABILITY

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Several papers have considered whether the mean global temperature record is statistically significant relative to the warming trend possible due to the natural variability of the climate system. However, previous work is not definitive due to the qualitative nature of the results and/or the use of a single General Circulation Model run as representative of the natural climate variability. I show that the natural variability of the system, as represented by pre-Industrial time series of atmospheric temperature variations, is statistically stationary and the autocorrelation of the time series is determined. Model global and regional time series statistically identical to those observed are then generated in monte carlo simulations to quantitatively determine the likelihood that the mean global warming and regional warming trends are statistically significant relative to the natural variability. Both the global and regional warming trends are found to be entirely consistent with natural variability.

THE IMPACT OF A COMPLEX LAND-SURFACE SCHEME ON THE RESULTS OF A CLIMATE CHANGE SIMULATION

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Most climate change experiments have been carried out with GCMs coupled to simple land-surface schemes. In this study, the impact of upgrading to a complex land surface on the simulated climate change will be analysed.
Within the project "Land-surface processes and climate response" two time-slice experiments for a climate with enhanced CO_2 concentration have been carried out. The oceanic surface conditions produced by the Hadley-Centre were used. The first time-slice was performed with the standard BUCKET scheme, which has been in use in most GCMs, the second one uses the complex scheme SECHIBA, which includes an explicit representation of the canopy. The impact on the hydrological cycle over continents in a changed climate will be the focus of the analysis.
A third time-slice experiment will be performed in which the surface conductance will be changed to represent the response of the vegetation to a CO_2 enriched environment. This effect will be compared to that of the change in land-surface schemes.

COMPARISON OF ATMOSPHERE MODEL AND COUPLED MODEL CLIMATE CHANGE DETECTION ESTIMATES.

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We show a new approach to climate change detection and attribution using an atmospheric general circulation model (AGCM). Ensembles of AGCM runs were forced with the observed history of sea surface temperature (SST) and sea ice extent and a variety of forcing factors added incrementally.
We compare these runs from those from coupled model (CGCM) runs forced with the same changing anthropogenic forcings. The AGCM detects a signal that is additional to any feedbacks between the anthropogenic forcing and the ocean. We show that the "residual" anthropogenic signal in the AGCM is not much smaller than the CGCM signal. For zonally averaged vertical profiles of temperature, the AGCM internal variability is on average substantially less than that of the CGCM. Thus we detect anthropogenic influences at a clearly statistically significant level in the troposphere and lower stratosphere.
However, only a CGCM can simulate the full impact of anthropogenic forcing on the climate, so the AGCM provides a complementary detection and analysis method. Accordingly, the Hadley Centre has now started parallel runs of an AGCM and a CGCM with the same time-varying forcings, where the CGCM has the same atmospheric component.

SIMULATED CHANGES IN BAROCLINIC WAVE ACTIVITY OVER THE ATLANTIC: A NAO VARIABILITY EFFECT?

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In accordance with a number of other GCM experiments, the coupled ocean–atmosphere GCM ECHAM4(T42, L19) + OPYC3 simulates an increased upper air stormtrack activity (bandpass filtered 500 hPa geopotential height variability) over the East Atlantic and Western Europe with increasing CO_2 forcing. A consistent signal is also found in the distribution of surface cyclones. While the deepest cyclones are located over the central Atlantic for all CO_2 forcings considered, the cyclone depth distribution is shifted towards lower core pressures over the East Atlantic and European sector. Previous observational studies link such a distribution also with the variability of the North Atlantic Oscillation (NAO). It turns out that the anthropogenic change in baroclinic wave activity cannot be regarded as an artefact of the particular dominating NAO phases during the simulation episodes considered. Although the signal to noise ratio is rather low, there are indications of a systematic change towards higher mean NAO index values with increasing greenhouse gas concentrations.

INTERPRETATION OF WINTER WARMING AT NORTHERN HEMISPHERE CONTINENTS IN 1977-1994

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Northern Hemisphere December-March near-surface temperature and pressure anomalies of 1977-1994 relatively to 1946-1976 are considered. These anomalies can be decompose into two almost orthogonal components. The first one reaches its maximum in 1977-1988. Main features of anomalies of 1977-1988 can be obtained as the atmosphere general circulation model (AGCM) response to sea surface temperature anomalies observed in 1977-1988. The second component reaches its maximum in 1989-1994. Main features of anomalies of 1989-1994 relative to 1977-1988 can be obtained as the AGCM response to low stratosphere ozone depletion observed in 1989-1994.
Model response to low-stratosphere ozone depletion was studied. It was shown that it almost coincides with the dominant mode of model low-frequency variability. The same is true for the observed anomalies of 1989-1994. Additional AGCM runs showed that large response to a small low-stratosphere external forcing can be obtained if the external forcing (in our case anomalous zonal mean radiative heating) is spatially correlated with the spatial structure of zonal mean vertical movement associated with the dominant mode. This condition is satisfied for observed low-frequency variability and low-stratosphere ozone depletion. So, real atmosphere can be strongly sensitive to small variations of the ozone in low stratosphere.

SEMI-EMPIRICAL MODELS OF AGE TRANSFORMATION OF THE CLIMATE OF UKRAINE FOR MODERN ERA

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There were obtained semi-empirical models of climatic fields of the following characteristics of the climate of Ukraine: meteorological norms (average for the period 1961-1990), dispersion from year to year and coefficient of linear trend (period 1900-1990) land-surface temperatures and intensity of atmospheric precipitation. The models are based on representation of time dependency of the mentioned climatic characteristics in form of three items (annual component and two harmonic components) and approximation of the dependency from geographical co-ordinates by linear polynomials.
It was found that changeability of land-surface temperatures from year to year is approximated by normal (Gauss) distribution. There was considered the statistic hypothesis regarding the choice of the approximation scheme of changeability distribution of atmospheric precipitation intensity on the basis of gamma-distribution or log-normal (log-Gauss) distribution. There was made an analysis of possible physical causes responsible for formation of received particularities of age transformation of land-surface temperature climatic fields and intensity of precipitation in Ukraine (decrease of summer temperature in south-west regions of Ukraine, decrease of annual intensity of precipitation in north-west regions).

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poster

NONLINEAR PROCESSES IN GEOPHYSICS (NP)

NP1 Scaling, multifractals and nonlinear variability in geophysics

Convener: Schertzer, D.
Co-Convener: Lovejoy, S.M.

01 Scaling, multifractals and nonlinearity in Solid Earth (co-sponsored by SE)

Convener: Schmittbuhl, J.
Co-Conveners: Bak, P.; Turcotte, D.L.

VARIATIONS OF PREDICTABILITY OF STRONG EVENTS IN A HIERARCHICAL MODEL OF SEISMICITY

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Predictability of strong events in a hierarchical model representing general features of seismicity is considered. A simple algorithm of prediction of strong events based on variations of the average magnitude is applied in order to investigate possible variations of the predictability.
Two kinds of variations of the predictability are obtained for the given algorithm. The predictability strongly depends on parameters of the model: predictable and unpredictable synthetic catalogs exist. Strong temporal variations of quality of prediction is obtained for the fixed algorithm and parameters of modeling. Temporal variations are also observed for the optimal threshold of the prediction. Observed variations may explain variations in the predictability of strong earthquakes in different seismic regions and the difference between the retrospective and forward prediction.

BURRIDGE-KNOPOFF MODEL AND SELF-SIMILARITY

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The seismic processes are well known to be self-similar in both spatial and temporal behavior. At the same time, the Burridge-Knopoff (BK) model of earthquake fault dynamics, one of the basic models of theoretical seismicity, does not posses self-similarity. In this article an extension of BK model, which directly accounts for the self-similarity of earth crust elastic properties by introducing nonlinear terms for inter-block springs of BK model, is presented. The phase space analysis of the model have shown it to behave like a system of coupled randomly kicked oscillators. The nonlinear stiffness terms cause the synchronization of collective motion and produce stronger seismic events.

EXPERIMENTAL ANALYSIS OF FRACTURE RUGOSITY IN GRANULAR AND COMPACT ROCKS

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Self-affine properties of the rugosity geometry for fractured granite and sandstone samples have been compared using two experimental techniques. Mechanical profilometry measurements on granite confirm that Hurst's exponent H is close to 0.8 over the full experimental range ($50\mu m - 10cm$) as reported previously. For sandstone, the rugosity spectrum is independent on the fracturation velocity but follows a power law only above a cutoff length scale of the order of the grain size. Moreover, the value of H in the self-affine part is distinctly smaller (0.45 ± 0.05) than for granite. Numerical simulations modelling the faceted shape of the sand grains reproduce the cutoff effect while keeping the value of H unchanged. The different H values in granite and sandstone may reflect the extragranular nature of fracture in the latter case. These results are compared to measurements of the lengths of shadows on such surfaces illuminated under grazing incidence. A power law distribution of the lengths with and exponent -1-H is expected up to a cutoff value depending on the amplitude of the rugosity and on the incidence angle. Diffusion and reflexion phenomena give varying light intensities in shadows requiring the use of a local thresholding algorithm. Images of large aspect ratio (8000 x 600) are used to improve the measurement statistics on the distribution. Results obtained with this technique are in fair agreement with mechanical profilometry measurements.

BEHAVIOR OF THE DIVERSITY OF FRAGMENTS IN PLATE BREAKING

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Fragmentation plays an important role in many geophysical phenomena e. g. in tectonics, weathering, and natural and artificial explosions. In the present work, we study the fragmentation of brittle solids (cement and cement-gypsum plates of square shape and different sizes) under application of periodic impulsive forces, emphasizing the time dependence of the diversity of fragments, D(t), which is defined as $D(t) = \Sigma_s \Theta\ (n(s,t))$, where $\Theta(x) = 1$, if $x > 0$, and 0 otherwise. We have observed from the experiments several relationships between D(t), the total number of fragments, N(t), and the size of the plates. Extensive computer simulations of the processes using highperformance workstations were made and agree with the experimental data. Among other relations we have found (i) a robust scaling relation between the maxima of N(t) and D(t), i.e. $N_{max} \sim D_{max}^2$, (ii) the number of fragments of size s at the time of maximum diversity, n(s), scales as $n(s) \sim s^{-1.8\pm0.1}$, in close agreement with a recent study of self-organized criticality in fragmenting.

PRINCIPLE OF FASTEST RESPONSE IN GEOPHYSICS, HYDRODYNAMICS, ETC.

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The principle says: if we know the generation rate $q = dA/dt$ of a certain value A, then $A \approx q\tau$, where τ is the shortest time the system in consideration has. In nature we often know q, such as the solar constant, or the geothermal heat flux for dynamics of atmosphere and ocean, or geodynamics. In hydrodynamics the comparison of times due to various terms in the Navier-Stokes equation gives usual similarity criteria of Reynolds, Rossby, Mach, etc. The principle reproduces readily all major results of hydrodynamics of forced flows in tubes, gravity field, turbulence in 3D and 2D, convection with and without rotation, mean wind on terrestrial planets, etc. New results are: frequency-intensity spectra for tropical cyclones, earthquakes, cosmic rays. Other applications of the principle may be envisioned. Relationship of the principle to the similarity theory, fractals will be discussed.

A FRACTAL APPROACH TO THE STRUCTURAL ANALYSIS OF MELANGES

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Melanges exhibit a pronounced non-coherent deformation and the recognition of this has traditionally let to the application of classical methods of structural geology developed in the ductile strain regime. Despite their chaotic appearance, melanges should show some degree of internal organization that traditional methods often do not take in right perspective. The wide variety of genetic mechanisms responsible of melanges formation complicates further on this picture. So far several studies have been showing that exist some kind of geometrical self-similarity relationship among different kind of melanges. The investigated relationships are mainly connected with the spatial pattern of blocks in matrix distribution and the frequency distribution of blocks themselves. Based on these fractal properties, our attempt concentrates on an alternative approach to the study and description of melanges. The studied disrupted sequence lies on western coast of Tuscany, near the city of Livorno. From a stratigraphic point of view it belongs to the "Palombini Shales" formation of Cretaceous age. It consists of a deformed series of bedded siltstones and limestones with interbedded shales that locally can become predominant over the competent lithotypes. Much of the sequence is coherent but disrupted units are present where the shales prevail and in association to a major shear zone. The deformation features recognized here are both symmetrical and asymmetrical blocks, isolated hinges often refolded, pinch-and-swell, while the matrix is characterized by scaly fabric, C-S structures and locally by some crenulation cleavage. From a geometrical point of view a melange can be considered as a binary system in which the blocks are discriminated by the matrix. The fractal model that better fits this system is the Sierpinski Carpet that can be theoretically built starting from a square generator unit, dividing each side of it in three equal portions and subtracting the central ninth each time for an infinite number of steps. Obviously, in natural systems, the best fitting model is a random version of the theoretical Sierpinski fractal, characterized by different fractal parameters that give us a sort of geometrical "signature" of melanges. The application of this models to the studied outcrops can lead to a better description of the spatial distribution of the different blocks helping in the 3D strain analysis. Besides, because of the promptness of that fractal method, it can also be used as a preliminary approach in alternative to classical, time-consuming methods.

DETERMINISM AND PRECURSORS IN EARTHQUAKE INTERVALS

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It is now widely believed that earthquakes constitute a highly nonlinear, probably chaotic process. In practical earthquake prediction, earthquake-related parameters are monitored in the field to detect so-called anomalies with precursory qualities by watching for 'peaks'. The same is true for analysis of spatial seismicity patterns whose temporal properties are also summarised in a time series. In the light of chaotic processes, however, it becomes clear that this simple approach does not reflect the necessarily higher degree of freedom of the underlying process. To be able to monitor properties of a chaotic system, analysis must instead be carried out in phase space. In the case of low-dimensional deterministic chaos one expects a so-called strange attractor in phase space whose properties should ideally be monitored for precursory behaviour. Unfortunately, nonlinear analysis of a great variety of real world signals has shown that the signals almost always posess too high a degree of freedom for numerical treatment, due to noise or the signals true inherent complexity. In this work, a series of earthquake intervals was constructed directly from an earthquake catalogue and a low dimensional deterministic structure was detected. Determinism of the attractor was confirmed by analysing phase randomised data. Furthermore, a Poisson distribution could not produce similar results. A first application of 'phase space monitoring' is shown and seems promising.

DETECTING SCALING LAWS AND NON-LINEAR DINAMICS IN GEOELECTRICAL SIGNALS: IMPLICATIONS WITH EARTHQUAKE PREDICTION.

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In this work precursory geolectrical time series measured in a seismic area of Southern Italy are examined, both in frequency and in time domains. The Higuchi fractal method to estimate the spectral power-law index has been applied, because the correlation between the length curve L(t) and the time interval t is better than the correlation between the power spectrum P(f) and the frequency f. In the time domain we analyzed the predictability of geoelectrical time series by using two forecasting autoregressive approaches: the global autoregressive approximation and the local autoregressive approximation. The first views the data as a realization of a linear stochastic process, whereas the second one considers the data as a realization of a non-linear deterministic process. The comparison of the predictive skill of the two techniques is a powerful test to discriminate low-dimensional chaos by random dynamics. Our findings are that in the geoelectrical precursory signals the stochastic nature is predominant. Then, all the possible implications with the short-term earthquake prediction are discussed.

SIZE-FREQUENCY DISTRIBUTION OF EARTHQUAKES IN HIERARCHICALLY ORGANIZED LOAD-TRANSFER MODELS

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Large hierarchically organized sets of elements (simulating asperities in a fault) are loaded to the point of complete failure. The fracture thresholds of individual elements are stochastically distributed, and the hierarchical structure for load-transfer is of the fractal-tree type. During the breakdown process there occur bursts (earthquakes) of several elements breaking simultaneously at a given load. Using Monte Carlo simulations we compute the frequency of bursts versus their size. This shows a gross power-law behaviour superimposed by a wavy pattern closely related to the coordination number of the fractal tree used for the load-transfer structure.

STADY OF NONLINEAR ELASTIC PROPERTIES OF ROCKS BY DYNAMIC CHARACTERISTICS OF TECHNOGENEOUS HARMONICS

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Seismic noise recordings from seismic stations "Obninsk", "Kislovodsk", "Arti" (Russia), and "Dobrushka" (Czech Republic) are analysed. All recordings contain industrial harmonics, such as 1 Hz, 1.25 Hz, 2 Hz, 2.5 Hz, etc. Nonlinear elastic properties of rocks in the vicinities of seismic stations can be estimated by coefficients of modulation of industrial harmonics by intense low-frequency processes, as storm microseisms and tides. To estimate nonlinear elastic properties of media, so-called "natural widths" of spectral lines of industrial harmonics and spectra of their amplitude and phase variations are studied. The results are compared with the results of numerical modeling. Conclusions are made about parameters of elastic nonlinearity of rocks in the vicinities of the seismic stations. To test these estimates, bispectral characteristics of seismic noise are calculated for the studied regions, and evaluation of parameters of elastic nonlinearity is made by bispectral amplitudes of seismic noise.

THE SELF-ORGANIZING CRITICALITY AS THE REASON OF THE GEOMAGNETIC FIELD REVERSAL

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According to the "hot' Earth's model, the region of the phase change on the inner core boundary can be presented in the form of the large number of interacting elements in which the phase change "condensation-evaporation" takes place. Such system can not in principle to achieve the thermodynamic equilibrium. It evolves to the critical state in which any small event causes the chain reaction; the system changes the direction of the phase change, for example, the advantage of condensation changes on the advantage of evaporation. In doing so, the change of the electric field polarity takes place arising on the phase change and, as result, the polarity of magnetic field changes.

A CREEP-SLIP MODEL OF EARTHQUAKE FAULTS: ANALYTICAL AND NUMERICAL RESULTS

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The classical spring–block model by Burridge and Knopoff (BK) is generalized in a way to account for the irreversible deformation (creep) of the fault interface in addition to rigid sliding displacements. By this generalization the driving forces are allowed to relax, and a rate and state-dependent friction with velocity softening is introduced. The model exhibits a new kind of short-wavelength instability which is associated to microfissuration during aseismic creep and by means of which parts of the fault self-organize to the critical state defined by the onset of velocity softening. The model is discussed in relation to the BK model (where this type of instability is absent) and compared to threshold models exhibiting self-organized criticality. Numerical results show intermittency of the seismic cycle and give power-law scaling of the event-size distributions. Implications of the model with respect to the predictabilty of earthquakes are discussed.

THE MAGNETIC FIELD, SCALING STRATIFICATION AND THE MAGNETIZATION SPHERO-SCALE

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The standard model of the structure of the earth is that that the horizontal and vertical structures are qualitatively quite distinct; the latter generally being refered to as "strata". Many geophysical fields have been shown to be scaling in both horizontal and vertical directions; this raises the possibility of a unified horizontal/vertical description and model based on generalized scale invariance (GSI). In certain cases such as the susceptibility (and by inference magnetization), it has been empirically suspected (Pilkington and Todeschuck 1993) that the spectral scaling exponents are different in the two directions. Stratification is very pronounced at small scales, but at larger scales the stratification dimishes. Eventually one power law exceeds the other (at a roughly isotropic scale called the "sphero-scale"), while at still larger scales, the stratification reverses direction (e.g. mountains have "roots").

We use the well-known statistical relationship between surface magnetic anomalies and the magnetization, showing that if the latter is scaling but anisotropic, the magnetic field will have a break in the scaling at the sphero-scale with different high and low frequency exponents that are related to the "elliptical dimension" (D_{el}) of the magnetization. Using a dozen aeromagnetic and susceptibility surveys and borehole data we show that $D_{el} \approx 7/3$ (a value 3 would indicate an unstratified earth, a value 2, totally stratified), and (as expected) a variable sphero scale (in the range $\approx$8 to $\approx$50km).

FRACTAL CHARACTER OF THE EARTH'S EVOLUTION

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The fractal properties and scaling of the Earth's magnetic field reversals are the peculiar characteristic of the Earth's evolution. The suggested model is based on that the thickness of the Earth's outer core was gradually increasing during the evolution; the formed convective cells with increasing the core thickness changed so that their number decreased when the cell sizes increased; the Earth's magnetic field polarity changed when the regime of convection changed; when the convection was steady, the magnetic field was stable; the convective cells arising in the core has the similar fractal structure and they belong to the same class of universality. The ordered multitude, characterizing the period durations of the steady convection and the period of its structure change and possessing the scale properties, is estimated with the multitude of the periods of the Earth's magnetic field reversals. Their community suggests that this model is equivalent to the nature of changing the polarity of the Earth's magnetic field.

A FRACTAL PIPE MODEL FOR VOLCANISM

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Volcanoes within volcanic arcs and fields are clustered in space and their eruptions are clustered in time. We utilize the pair correlation function, the number of pairs of volcanoes as a function of the radius separating the pairs, normalized by the number expected from a Poisson process, to quantify the clustering of volcanoes in several volcanic arcs and vent fields. Scale-invariant clustering is observed. The pair correlation function in time is used to identify scale-invariant clustering of eruptions in time. We also analyze spatial and temporal clustering in volcanic rocks with the Radiometric Databank of 11,986 dated volcanic rocks in the North American Cordillera and find scale-invariant clustering with statistics identical to those of distributed seismicity. In addition, the frequency-size distribution of eruption volume is a power law analogous to the Gutenburg-Richter distribution for earthquakes with a 'b' value of 1. In an attempt to explain these observations, we first consider a model for the spatial clustering of volcanoes and the size distribution of magma chambers in terms of a simple model of an upwelling instability of magma through the upper mantle and crust. This model geometry is then used in conjuction with a model for the flow of magma through upwelling channels that terminate at magma chambers with a pressure-dependent time-to-failure probability of eruption. The frequency-size distribution of eruptions and the clustering of volcanoes in space and eruptions in time are identical to those observed.

MULTIFRACTAL TOPOGRAPHY AND ITS BI-DIRECTIONAL REFLECTION FIELD

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The analysis of DEM's in recent years has led to considerable evidence that many topographic and bathymmetric fields display multiscaling characteristics over scales ranging from the size of the Earth down to at least 90m. Remotely sensed surface reflectivity fields also show multifractal statistics with roughly the same basic multifractal parameters; apparently only the non-conservative parameter H is significantly different.

Using simple theoretical models and numerical simulations we study the relationship between the scale-by-scale statistical properties of a given radiance field and those of the underlying topography profile. The statistics of the calculated radiance field are then compared with those of the known topography field, allowing direct comparison of the two fields' scaling parameters including those determining the anisotropy and morphology.

HETEROSCEDASTICITY, HURST, AND SURROGATE DATA: PERSISTENCE WITHOUT PREDICTABILITY

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The analysis of a variety of nonlinear geophysical data sets often reveals "long range dependence" which is in turn taken as an indication of enhanced predictability. It is illustrated that "long range dependence" need not imply any useful increase in predictability. This is the case, for instance, with seasonal heteroscedasticity; surrogate data methods for identifying this type of technically "nonlinear" behaviour are provided. Surrogate data consists of artificially generated data from a known process constructed so as to mimic some properties of an observed data set. Its value lies in identifying the lack of significance of a particular data analysis, when the same analysis of a "similar looking" data from the (known) surrogate process yields an result which is (known to be) incorrect. Of course, even if the observed data set can be distinguished from the surrogate data, it might be different for the wrong reason: if the wrong properties of an observed data set were mimicked, then the particular analysis may still be insignificant. Several examples are provided.

ANOMALOUS SCALING OF FRACTURE SURFACES

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We argue that fracture surfaces exhibit *anomalous* dynamic scaling properties akin to what occurs in some models of kinetic roughening. We determine the complete scaling behavior of the growth of local topography fluctuations of a brittle fracture in a granite block from experimental data. We obtain a global roughness exponent $\chi = 1.2$ which differs from the local one, $\chi_{loc} = 0.79$. Implications on fracture physics are discussed.

LOG PERIODICITY IN THE FOREST-FIRE MODEL

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The forest-fire model is one of three classic examples of models exhibiting self-organized critical behavior; the other two are the sandpile and slider-block models. Log-periodic behavior is fractal behavior with a complex fractal dimension. In the simplest form of the forest-fire model, a square grid of sites is considered. At each time step a site is randomly chosen, either a tree is planted on the site (if it is unoccupied) or a match is dropped on the site. If a match is dropped on a site with a tree, that tree and all adjacent trees burn. The sparking frequency f_0 specifies the number of trees planted (or attempts to plant) before a match is dropped. If $f_0 = 1/100$, a match is dropped after each 99 time steps. For very small firing frequencies (*i.e.*, 1/10,000 for a 128 x 128 grid) the frequency-size distribution of forest fires cluster at well defined peaks. These peaks approach the size of the grid and satisfy a log-periodic relation. This behavior can be explained in a straight-forward manner. The exponential growth of the forest density combined with a periodic triggering mechanism leads naturally to log periodicity. It is interesting to speculate whether observations of log-periodic behavior in natural phenomena such as earthquakes can also be explained in this way.

NP1

SELF-ORGANIZED CRITICALITY AS A RESULT OF HETEROGENUITY OF MEDIA: MIXED HIERARCHICAL MODEL

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We are interesting in investigation of general features and appearing conditions of critical behavior in self-similar systems. Two kinds of critical behavior are separated. An unstable critical behavior exists in isolated points, it is usually connected with a phase transition. A stable critical behavior such as the self-organized criticality exists in a nondegenerate area of system parameters. We consider a simple model where both kinds of criticality are achived.
A hierarchical model of defects representing a mixture of the simplest transition operators is suggested. Four kinds of system behavior are realized: stability, catastrophe, phase transition from stability to catastrophe and a stable critical behavior (SOC). The condition to obtain a stable critical behavior is determined in terms of parameters of the mixture. It is shown that the self-organized criticality expresses heterogeneous properties of the media.
Different precursory patterns for strong earthquakes reflecting concrete type of system behavior are described.

A SCALING LAW BETWEEN AN ELECTRIC PRESEISMIC ANOMALY AND THE MAGNITUDE OF THE ASSOCIATED EARTHQUAKE.

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Experimental results suggest that the electric earthquake precursors (EEP) emitted from various regions and recorded in a given field station have maximum electric field value E which is scaled to the magnitude M of the earthquake, by the expression: $\log E = \alpha M + b_i$ (1) where α is a positive slope factor lies between 0.3 and 0.4 and b_i is connected with peculiarities of the observational site. Recently a model based on the motion of charged dislocation (MCD model) has presented in order to describe the generation of EEP. It has concluded that in order to observe an EEP distributed emitting cells are required. In the present work the emitters simulated for simplicity by polarized spheres distributed in the earthquake preparation volume. Without the assumption of any underling generation mechanism, an induced polarization $P(t)=P_o\, u(t)$, u(t) is the step function, appears in the volume of the sphere. Since P varies with time the sphere behaves as a source of electric and magnetic field. Introducing the hypothesis that the number of emitting spheres N is scaling with their radius R as $N \propto 1/R^D$, we lead to an expression similar to (1) where $\alpha=(3-D)/2$. The experiment indicates that D lies between 2.2 and 2.6 leading to α values in the range 0.2-0.4, in comparison with the observed ones. The latter agreement suggests that the scaling law (1) is a result of the geometric distribution of the emitters in the earthquake preparation zone.

A CHARACTERIZATION OF NONSTATIONARY MULTIFRACTAL PROCESSES

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Multifractals are ordinary processes X(t) or generalized processes X[h(t)] that satisfy certain stochastic scaling conditions. For example, a multifractal X(t) satisfies $X(t) =^d r^{-H} A_r X(rt)$ for some deterministic H and some random A_r, with $E[A_r] = 1$, $r \geq 1$ or $r \leq 1$, and t in a certain range. The above scaling condition is of a global nature. In addition, the increments of X(t) may scale locally, in the sense that $X(t+\tau)-X(t) =^d r^{-H'} A_r'[X(t+r\tau)-X(t)]$ for some deterministic H' and stochastic A_r', r as above, and any given t and τ. In the special case when $A_r = 1$ deterministic, X(t) is self-similar. Self-similar processes with stationary increments have identical local and global scaling, with H = H' and $A_r = A_r' = 1$. Analogous global and local scaling properties apply to generalized processes X[h(t)]. We show how processes X(t) and X[h(t)] with various local and global, self-similar or multifractal, scaling properties are related to stationary processes and to processes with stationary increments and how such constructions determine the scaling parameters $\{H, A_r, H', A_r'\}$. These characterizations are extensions of a classic result by Lamperti (1962) for globally self-similar processes. An example of ordinary nonstationary multifractal is the model of annual maximum stream flows by Gupta, Mesa and Dawdy (1994), which is globally multifractal with A_r either lognormal or log-Levy. An example of generalized multifractal is the river profile model of Veneziano et al. (1998; this conference), which is globally self-similar (H = 1 and $A_r = 1$) and locally multifractal (H' = 1 and A_r' log-Levy or the product of a Bernoulli and a lognormal variable).

3-D ORE FRACTALS AND STRANGE ATTRACTORS IN THE TIME SERIES OF THE PRECAMBRIAN BANDED IRON FORMATIONS (BIF).

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An analysis of 100 BIF's magnetic distributions using Takens method showed that spatial variations of magnetite are an exhibition of the deterministic time history of the ore systems. It is established that inclinations of the D=f(d) plots defining a fractal dimension of attractors D=2.05-2.3. This means that magnetite distribution in the ore bodies after folding, metamorphism of BIFs, etc., is controlled and can be set by an interaction of a small number of variables.
Investigations of fractal geological objects (most of them are 3D bodies) as a rule are based on their 1D - 2D sections, or some indirect data (as in seismology). Such investigations, however, do not provide a strong basis for calculation of fractal dimensions. Unique geological and geophysical data of the Kirovogorskoye BIF deposit structures give a possibility to determine 3D fractal dimension of the BIF bodies (D=2.14).
Digital experiments in modelling of re-distribution of components, according to the model system of 8 variables (Si- Fe^{2+}-Fe^{3+}-Ca-Mg-Al-K-Na) show that there is a possibility that structures analogous to BIF bodies could be formed. This testifies that fractal structures of the Kola BIF's are not a random coincidence, but an evidence of functioning of a metamorphic-self-organization system.

NP3 Transport and mixing in geophysical flows

Convener: Legras, B.

06 Mixing in the interior of the Earth (recycling of subducted slabs) (co-sponsored by SE)

Convener: Ricard, Y.

QUANTIFYING MIXING IN NUMERICAL MODELS OF MANTLE CONVECTION

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Recent high-resolution seismic images of subduction zones appear to indicate that slabs extend into the lower mantle, possibly to the core-mantle boundary. This is consistent with a circulation pattern that encompasses the entire depth of the mantle and suggests efficient recycling of subducted slab. Models of the geochemical evolution of the mantle, on the other hand, seem to require several distinct "reservoirs" of differing mean age and trace element composition, suggesting that recycled slab is not efficiently mixed within the mantle. An important question in mantle dynamics is whether large regions can develop different residence times (maintaining distinct reservoirs), or whether a different explanation of the geochemical data is called for. We developed quantitative measures for assessing mixing in numerical models of mantle convection. Tracer particles, introduced to simulate subduction and formation of oceanic crust, form fractal distributions with dimensions that depend on the model parameters. The distribution of mean ages provides a measure of the geochemical evolution of different regions. We investigate the role of viscosity stratification across the transition zone and in the D″ region on formation and destruction of heterogeneities. Viscosity stratification slows the transport of slabs across the transition zone, but the slowed transport does not stratify the mantle geochemically. Old slab material survives longer in a viscously stratified mantle, but the recycled slab is not concentrated into discrete reservoirs.

MANTLE MIXING: INFLUENCE OF 3-DIMENSIONALITY AND VISCOSITY STRATIFICATION

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Mixing properties of the mantle remain puzzling. One does not precisely understand how the mantle convection can destroy the chemical and isotopical heterogeneities of the lithosphere, and in particular, what kind of mixing times are related to this re-homogenization. While geodynamicists favor efficient mixing by deep slab penetration, various geochemists advocate for the existence of unmixed reservoirs. We compute various 3-D cavity flows with imposed surface conditions mimicking tectonic plates and advect passive tracers in order to quantify their mixing abilities. The 3-dimensionality of our model allows us to choose plate geometries with both converging/diverging margins which induce vertical transport and strike slip margins which only mixes the mantle on horizontal planes. Internal masses simulating subducting slabs can also be imposed. We study the effects for the mixing rates on the one hand, of the toroidal over poloidal energy ratio (e.i. the relative importance of surface strike slip to diverging motions), and on the other hand, of a viscosity increase in the lower part of the system (which mimics an 'upper' and a 'lower' mantle). We will see that the time-dependence of the flow is not necessary to obtain chaotic areas with efficient mixing in 3-D models. Simple flows will also illustrate the possibility to maintain some unmixed reservoirs even without viscosity stratification. We will discuss different ways of quantifying the mixing efficiency, and present scale-dependent mixing times for various models of the Earth's interior.

Is there a missing link between geochemistry and geophysics of the convective mantle ?

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While in Geophysics, information about the convecting Earth mantle is carried by signals in which spatial characteristics of the medium through which these have propagated are particularly important, in Geochemistry, measurements rely on rock samples, the matter of which has essentially lost most of the memory of their travel throughout the mantle until the outcrops where they have been picked up. Up to now, one fruitful approach developped in Geochemistry is by considering reservoirs and budget complementarities, approach for which isotope tracers are of the most pertinent geochemical tools. However, this "globalistic" approach gives little information about spatial disposition of these reservoirs. A refinement of this is to consider the heterogeneity of the reservoirs through the isotopic ratio distributions, which is a purely statistical point of view rather than a spatial one. Evolution models of convective stirring can thus be tested for being able to sustain the kind of steady-state heterogeneity that these isotopic distributions quantify. Thus, in order to generalize these direct observations provided by geochemists from the analyzed rock sample collection to their whole source reservoir, one must first be fully convinced that this sampling is either representative of its mantle source reservoir, and/or that biases can be evaluated. If reweighted statistics are an attempt to bring an affordable solution for the second "drawback", the first assumption can only be approached through convection modelling in which a ridge sampling scheme is taken into account.

EFFECTS OF TOROIDAL FLOW AND RHEOLOGICAL HETEROGENEITIES ON MIXING IN THE MANTLE

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Large scale mixing of chemical heterogeneities in the Earth's mantle is accomplished by the stretching and folding motion associated with mantle convection; diffusional processes are only important on centimeter length scales. Chaotic flows will promote effective mixing; these can be produced by time dependent flows and also by the presence of toroidal components of flow (which are only present in 3 dimensions). Plate tectonics produces both in the mantle, and hence mixing should be effective, especially in the upper mantle where the effects of plate flow are largest. The lower mantle may be less well mixed owing to its higher viscosity and the relatively small toroidal flow. Studies of simple flow systems with poloidal and toroidal flow components demonstrate the chaotic nature of the flows and constrain the time constants for efficient stirring of the mantle. Considerations of time scales for the Earth indicate that the upper mantle should be well mixed. Geochemical observations indicate the presence of long–lived heterogeneities in the mantle. Simple flow calculations show that viscosity heterogeneities strongly influence mixing. Weak blobs are rapidly deformed and dispersed in a larger scale flow, while high viscosity blobs can resist deformation and dispersal for times that are geologically long. Such heterogeneities may account for geochemical reservoirs in the mantle.

CONVECTIVE MIXING CONTROLLED BY PHASE TRANSITIONS AND THE SIZE DISTRIBUTION OF CHEMICAL HETEROGENEITIES IN THE EARTH'S MANTLE

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It is now generally recognized that the convective circulation in the Earth's mantle is neither completely layered by the 670 km discontinuity nor does it cross this horizon completely unhindered. Many non-linear simulations of thermal convection in this region of the Earth have demonstrated the critical role played by the endothermic phase transition that defines this horizon in controlling the mass exchange between the lower mantle and the upper mantle and transition zone. Geochemical measurements of mid-ocean ridge and ocean island basalts show different degrees of elemental depletion indicating the existence of at least two distinct chemical reservoirs in the Earth's mantle which are often associated with the lower mantle and upper mantle and transition zone. The scale of chemical heterogeneities within these reservoirs, which are likely controlled by the scale of the mass flux events transiting the 670 km horizon, remain poorly constrained. We will describe a suite of high resolution numerical simulations of thermal convection in the Earth's mantle which include the effects of the endothermic phase transition in which we characterize the size distribution of trans-670 km mass flux events. We will demonstrate that for certain parameter regimes, the size distributions display scale invariance.

MIXING IN VIGOROUS, TIME-DEPENDENT 3D CONVECTION

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An understanding of the mechanism of mixing in highly viscous convecting fluids is of crucial importance in explaining the observed geochemically heterogeneous nature of the Earth's mantle. Using constant viscosity numerical experiments, we describe the mixing mechanism of time-dependent Rayleigh-Bénard convection with an infinite Prandtl numer in a three-dimensional rectangular container. Mixing is observed by following the positions of passive tracers advected by the flow. The major mixing mechanisms may be described in terms of the within-cell mixing and the cross-cell mixing. The flow structure in which tracers move on toroidal surfaces, that was previously observed in steady-state 3D convection systems is perturbed by boundary layer instabilities in the time-dependent experiments. This flow structure allows a very efficient exchange of mass between the boundary layers and the core of the convection cell even in the absence of time-dependence. We compare this results with calcluations carried out in two spatial dimensions. The inferred mixing rates are observed to be relatively insensitive to initial tracer location, but the timescale for mixing, t_m, decreases with increasing Rayleigh number. The timescale of mixing is an important constraint on the large scale structure of the Earth, because large-scale geochemical heterogeneities persist to the present day, implying that the mantle is not well mixed.

Mixing Efficiency in the Upper Mantle

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We have investigated the relative mixing efficiency between Newtonian and non-Newtonian temperature-dependent rheologies operating in the upper-mantle. This method is based on assembling many passive tracers on line . The particles are dynamically redistributed at each time-step. They are then advected by the velocity field produced by thermal convection . Up to one million tracers per line and ten lines ten lines have been employed for following the the time-history of a source of heterogeneity. Based on the mass transfer history through the horizontal layers we can construct the statistical characteristics and follow the dynamics over a phase plane consisting of the depth and time . The mixing characteristics are different between the two rheologies. Non-Newtonian rheology retains long-living horizontal structures, while Newtonian rheology produces vertically stratified columns. Greater amount of deformation is produced by the Newtonian convection. Mixing is less efficient for non-Newtonian rheology as islands with unmixed material still persist. The length of the lines grow with time in a power-law fashion for Newtonian . The lines produced from both rheological flows display fractal behavior, which increases with time.

GEODESY (G)

G1 Environmental effects on gravity and intercomparisons with other techniques

Convener: Hipkin, R.G.
Co-Convener: van Dam, T.M.

THE EFFECTS OF OCEAN AND SHELF TIDES ON ABSOLUTE GRAVITY MEASUREMENTS

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Absolute gravity and precise relative gravity measurements are affected by the loading and attraction of shelf and ocean tides. Several projects are currently in progress which are using absolute gravity measurements to determine vertical crustal movements to an accuracy of 1 mm/year. The evaluation of the loading and attraction is particularly important when absolute gravity is used at near coastal sites to remove the vertical crustal movement component from relative mean sea level measurements at tide gauges. Along the Atlantic coast of Europe the ocean tidal loading amplitudes (including attraction) are typically 9 to 18 microgals. The oceanic effects decrease towards the centre of the continent, but the amplitudes are still over 1 microgal at Wettzell, FRG. Since the standard deviation of drop sets over a 24 hour period is normally used as an error estimate on the absolute gravity value at a site, it is important to model these effects and to remove them from the observations. This talk will review recent progress on this topic using examples from recent projects and will also compare the results with parallel projects which use GPS measurements to determine vertical crustal movements.

CONTINUOUS GRAVITY RECORDING WITH SCINTREX CG-3M METERS: A PROMISING TOOL FOR MONITORING ACTIVE ZONES

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We have acquired continuous series of microgravity measurements using several Scintrex CG-3M gravity meters. The 1 μGal resolution meters have been installed side by side to perform identical data acquisition for several weeks in 1997. We present and compare the instrumental responses obtained for the various meters (measurement series of gravity field, std dev, internal temp, tilts) and analyze their correlation with simultaneous meteorological recordings. The data have been processed in order to a) establish the mid-to long-term relative stability and the accuracy of the different instruments, b) estimate the contribution of instrumental effects on gravity measurements, c) quantify the amplitude of the time variations of the gravity field that might be detected with such instruments. Results of the analysis of gravity differential signals, gravimeter calibration and tiltmeters resolution are presented here. This study reveals that temporal variations of the gravity field could potentially be detected in the field, with an accuracy of about 5 to 15 μGal, by permanent networks of Scintrex CG-3M gravity meters. This result is of particular interest in the field surveys of temporal gravity changes related to environmental or geodynamical processes where expected variations are greater than few tens of μGal. Application to the monitoring of active volcanoes is also discussed here.

GRAVITY-MICROSEISMIC APPROACH TO PREDICTION OF BURIED ACTIVE FAULTS

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The data on delineation of active fracture zones obtained using gravity-microseismic technique are presented. The technique is based on the fact that vibration of the foundation affects the position of the pendulum of a sensitive system of high-precision gravimeters established back in the 1970-s. Vibration-induced systematic deflections of pendulum (up to 0.1 mgal) are indistinguishable from real Δg. Gravimetric and simultaneous microseismic measurements performed at a number of continental fracture zones crossing important objects such as nuclear power stations, dams, dikes, trunk pipelines, etc. proved to be highly effective. It was shown that these zones are not the whole entities but rather the sequences of mobile and immobile areas. Before and during the seismic events it is the mobile areas which exhibit increasing microseismic activity resulting in discrepancies in gravimeter readings. Since the microseismic amplitude changes are often within the threshold of resolution of seismic machinery, vibration-induced gravity anomalies are unique highly-sensitive indicators of the level of fracture zone activity. The proposed approach is described in terms of structural dynamics. This combined approach proved to be considerably more effective in the mapping of buried active fracture zones than each technique (gravity or seismic) used alone.

EXPERIMENTAL INVESTIGATION INTO THE ORIGIN OF TARES INDUCED BY GROUND VIBRATION IN LACOSTE & ROMBERG GRAVITY METERS

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In January 1997 a dynamic micro-gravity survey conducted on the volcano of Montserrat Island, was subject to a high number of temporary tares from an otherwise reliable gravity meter. Correlation of gravity reading times with seismic data showed that spurious readings coincided with periods of high broad band volcanic seismic tremor. Retrospective analyses identified that temporary tares lasted for the duration of the broad band seismic tremor. The problem of readings being effected by an external vibrational force is not unique to volcanoes. Hallinan 1991, identifies temporary tares that occurred during a survey around pumping wells. A series of controlled experiments have been undertaken to assess the mechanical response of 5 L&R gravity meters. All experiments are conducted within an anechoic chamber and experimental apparatus are mounted on anti-vibrational optical tables (AVOT), eradicating all background vibrational noise. A gravity meter is placed on an AVOT and a Ling Dynamics Series-403 shaker induces motion over a range of 2 to 200Hz. A laser Doppler vibrometer mounted on a second AVOT is used to measure the vibrational amplitude of table and gravity meter. The spectrum is then determined using an Onosokki FFT Analyser. Experiments have shown that gravity meters undergo temporary tares at specific vibrational frequencies.

TIME-DEPENDENT GRAVITY AND ENVIRONMENTAL OBSERVATIONS AT MOXA OBSERVATORY: FIRST RESULTS

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In the scope of the expansion of the seismological observatory Moxa (Thuringia, Germany) into a geodynamic broadband–observatory a continuous monitoring of temporal gravity changes is carried out for a couple of weeks. First results of these gravity observations are presented. In order to study and correct meteorological influences on gravity data from the observatory–owned meteorological station are available. Among other parameters barometric pressure, temperature and air humidity are observed. These meteorological parameters are recorded using the same sampling rate (10 s) as for the recording of the gravity variations. Results of the first analyses of these time–series regarding a common signal contents with gravity are discussed. Signals with periods ranging from 1 min up to 14 days are under consideration.

INFLUENCE OF TOPOGRAPHY AND GROUND WATER CHANGES ON SECULAR GRAVITY CHANGES

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The correlation of observed secular gravity changes with environmental parameters is poor. The most hitherto published gravity changes are too big and cannot be explained by reliable simple models of environmental parameters. Similar results were obtained from a repetition gravity network in Turkey where beneath gravity changes also height changes as well as air pressure precipitation and ground water level are available. Simple multiple regression models can not model the gravity changes. Estimated regression coefficients are insignificant and unreliable in comparison to physical models.
A significant improvement was obtained, if the ground water table is modelled in first approximation by the smoothed topography in the vicinity of the gravity stations. The new topographic model of ground water table explains together with precipitation the gravity changes .

MICROTREMOR SPECTRUM DYNAMICS, GEOCHEMICAL AND GRAVITY DATA IN THE MONITORING OF THE INTRAPLATE FRACTURE ZONES

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Microtremor, gravity and water-helium measurements were taken in the two areas within the sedimentation basin of Russian platform. The results show that the blocks earlier regarded as stable consist of the smaller blocks separated by active fractures. The analysis of microtremor polarization within these smaller blocks showes that some blocks move within the horizontal plane, others - within the vertical plane, and some blocks move within the three planes. Combined gravity and microtremor analysis allowed to predict the heterogeneity both in the sediments and in the foundation. Some of the discovered active fractures penetrate the foundation as shown by the water-helium data. It should be noted that the parameters of block movements were established only when registering the accelerations of 10^{-4} - 10^{-5} m/sec^2 corresponding to the minute amplitudes of microseisms of 10^{-9} - 10^{-10} m in the frequency range from 15 to 200 Hz. Monitoring of these minute amplitudes increases the reliability of predictions of block displacements with higher amplitudes (in the range of several mms) dangerous for the important objects of high ecological risk such as nuclear power stations, trunk pipelines, etc.

ESTIMATES OF ENVIRONMENTAL EFFECTS IN SUPERCONDUCTING GRAVIMETER DATA

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The gravimeter is an integrating sensor measuring gravitational variations associated with mass redistributions in its near and far surroundings. Therefore, the recordings include gravitational effects of different sources. The separation of these effects is necessary for their investigation. Besides the gravity, the environmental data have to be measured for this separation.
Environmentally induced gravity effects are normally treated as disturbing signals in the gravity data. Therefore, they must be removed accurately for the interpretation of the time behavior of the gravity field.
Different models are used for estimating the order of the effects caused by the environmental parameters of the atmosphere (atmospheric pressure, snow cover, rainfall) and the hydrosphere (groundwater table, soil moisture). The models are based on Bouguer plate, Green's function and Hankel transformation methods.
The reduction for atmospheric pressure and groundwater table is performed on Superconducting Gravimeter data. The admittance coefficients are determined and the quality of the reduction is discussed.

GRAVITY OBSERVATIONS IN GREENLAND: HOW TO SEPARATE ENVIRONMENTAL EFFECTS AND ICE MASS BALANCE SIGNALS

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The aim of relative gravity observations in West Greenland is to investigate signals which are caused by short-term ice mass changes. In order to separate effects we are not interested in, one has to take into account environmental effects (besides the tidal signal), like the atmospheric pressure variation and the ocean loading effect. The possibility to determine or model these effects will be discussed, especially with regard to the unique topographic and climate conditions in West Greenland. From the geodetic point of view it will be shown how environmental effects, which can be regarded as systematic effects, could be eliminated by choosing a suitable observation regime and by carrying out repeated observations.

INFLUENCE OF VARIATIONS IN SUBSURFACE WATER STORAGE ON GRAVITY AT THE XI'AN ABSOLUTE GRAVITY STATION.

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Absolute gravity measurements made in June 1990 (Sino-Finnish campaign) and September 1993 (Sino-German campaign) at the Xi'an station of the China Gravity Basic Net show an apparent 34 μgal decrease in gravity. Relative gravity measurements from a distant mountain site repeated in 1990, 1991, 1992, 1993, and 1995 indicate a gentler slope of about -4 μgal/yr. The soil is silt and clay. The groundwater is at around 20 m depth. We do not have any data on groundwater prior to September 1993, but from that time to October 1996 its level fell by 4 m. Given the effective porosity of 32% this could correspond to a decrease of 54 μgal in gravity. However, the porosity was determined from disturbed near-surface samples, at depth it might be less due to compaction. From this information, rainfall statistics, soil properties, and vegetation cover we try to infer the variation in subsurface water storage, and its influence on gravity.

EFFECT OF VIBRATIONS ON ABSOLUTE GRAVITY OBSERVATIONS

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Observed long-term gravity variations comprise various environmental effects (redistribution of atmospheric, hydrologic and oceanic masses, tides) that are a matter of separate interests. Another effect occurring everywhere is vibration disturbances. Ambient seismic noise reduces short-term resolution of gravity observations. Being site-dependent, systematic errors due to gravimeter/floor recoil effect can considerably distort shallowly spaced results. That is why the modeled environmental effects must include influence of both ambient and internal vibrations. To solve these problems, an absolute gravimeter is analyzed as a linear dynamic system in the frequency domain. Obtained frequency responses are simple tool to investigate gravimeters' errors caused by vibrations with any spectrum. Firstly, the developed method was used to design an anti-vibration system grounding on invariance principle. Vibration accelerations were independently detected by the high-sensitive piezo-electric accelerometer and then further transformed into correction according to the mathematical model of our rise-and-fall absolute gravimeter. As a result, standard errors were reduced over 3 times. Secondly, frequency responses of a gravimeter were applied to investigate variation of gravity value with the drop length and starting interval. Assuming parameters of the FG5 absolute gravimeter and considering real possible coherent vibrations, it was shown that unrecognized systematic errors of order 10 μGal can be detected. Besides, various results of related experiments can be easily explained using the proposed frequency response technique.

AIR PRESSURE AND GROUNDWATER EFFECTS AT FIDUCIAL SITES SEEN BY CONTINUOUS GRAVIMETER REGISTRATIONS

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To underline vertical movements detected by continuous GPS measurements and variations in the gravity field caused e.g. by changes in the sea level, precise gravity observations are performed at fiducial sites. At selected stations superconducting gravimeters have been installed to study short term (daily up to annual) gravity variations. The understanding and modelling of such effects like influences resulting from air pressure and groundwater variations are important for the reduction of precise absolute gravity measurements which will be used to determine secular trends in gravity.
In the framework of SELF II a dedicated experiment is started in Medicina / Italy where a superconducting gravimeter runs in parallel with a permanent GPS receiver and repeated absolute gravity measurements are carried out. The geological regime in the Po delta valley is quite different from situations where other superconducting gravimeters are installed. The consequences for the interpretation of the gravity variations are discussed and compared with existing results.

METHOD OF DETECTING ABSOLUTE GRAVITY VARIATIONS WITH THE SUBMICROGAL RESOLUTION LEVEL

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Various environmental effects result in gravity variations. To detect such variations in long-term absolute gravity measurements, both random and systematic instrumental errors must be as much as possible eliminated. Modern absolute gravimeters employ interferometric observation of a freely falling body in a vacuum. To construct time-distance events of a falling body, sinusoidal fringe signal can be either continuously recorded (following by T. Tsubokawa and I. Murata) or converted into zero-crossings (following by J. Faller and A. Sakuma). An alternative principle of processing electronics involves digitization the fringe signal and fitting it to the sinusoidal wave with the linearly-growing frequency (proposed by M. Zumberge). We describe another method when the high-resolution digitization the fringe signal is combined with the second-differences method. As a result, we consider standard linear model of a free-fall motion that implies absence of systematic errors. Theoretical calculations and simulation experiment show that new method approaches a submicrogal resolution level. We estimate random and systematic errors of the processing electronics in a single drop as 0.2 μGal and 0.1 μGal respectively. Being much simpler than non-linear algorithms, this method is used in a new generation transportable NAOM#2 gravimeter that is suitable for long-term gravity observations.

G1

THE CORRECTION OF THE PRESSURE EFFECTS FOR THE SUPERCONDUCTING GRAVIMETERS IN MEMBACH, BELGIUM AND BOULDER, COLORADO

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Using global pressure charts, we calculate the influence of atmospheric pressure changes on vertical gravity measured by two superconducting gravimeters: one in Membach, Belgium and one in Boulder, Colorado. When compared to a single admittance correction, it turns out that a global correction is able to significantly reduce the residual signal of the instruments in the frequency band below 0.5 cycles per day. However, due to the coarse temporal sampling of the global pressure grids, this correction makes no sense for higher frequencies. We therefore used an alternative approach, using the barometer signal of the instrument as a first approximation, and using the pressure grids for further refinement. In this way, we were able to calculate a pressure correction that is superior to the single admittance in all frequency bands. Comparison of the results at the two sites provides insight into the effects of local topography and meteorology.

NON-TIDAL GRAVITY VARIATIONS OBSERVED BY SUPERCONDUCTING GRAVIMETER GWR T020

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We present the results of gravity residuals observed by superconducting gravimeter, GWR T020, in Metsähovi, for years 1994 - 1997. The gravity data is offset corrected and detided using the model at the site. As an auxiliary the level of groundwater is observed in the borehole nearby. After removal the drift and the influence of the atmospheric pressure the effect of the polar motion is clearly seen in the recording. The groundwater level also correlates with the gravity residuals. Finally the traces of microseismicity due to the atmospheric effect is discussed.

G2 Recent crustal movements of coastal regions: new geodetic, geologic and geophysical results

Convener: Pirazzoli, P.A.
Co-Convener: Bastos, L.

Sponsorship: IGCP (UNESCO-IUGS) Project 367 "Rapid Coastal Changes in the Late Quaternary"; INQUA Commission on Neotectonics; INQUA Commission on Quaternary Shorelines

SEA LEVEL CHANGES AND TECTONIC STABILITY: PRECISE MEASUREMENTS IN 3 COASTLINES OF ITALY CONSIDERED STABLE DURING LAST 125 KY

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The mobility of the Mediterranean coasts, as shown by Late Pleistocene-Holocene shorelines, appears highly variable. Many studies have measured very fast uplift or subsidence rates, even in recent times, related to intense tectonic-seismic activity, mainly concentrated in the eastern sector of the Mediterranean Sea. On the contrary, other areas appear relatively stable, mainly in the Western and Central Mediterranean. Along the Italian coast, the most widely distributed and therefore useful reference datum is the paleo sea level related to stage 5 (125 ky), which shows relevant differences even in adjoining areas. In the present study, this marker (inner edge or notch) has been safely identified along 3 sectors of the Italian coast generally considered *stable*: E Sardinia, S Latium and NE Sicily. Main novelties of these measurements are their accuracy, due to the use of a Total Station carefully positioned on present-day abrasion platform, which has permitted to greatly reduce the uncertainty, and their continuity along the investigated coasts. In Latium the top of the Eutyrrhenian was found to vary between -6 and +9.8 m a.s.l.(± 1.5 m) along a 90 km long coast. A well carved Eutyrrhenian notch was followed for 40 km along the coast of Sardinia, gradually varying in elevation between 7.7 and 10.3 m a.s.l. (±25 cm). In Sicily, the inner edge of the Eutyrrhenian scarp was followed for ca. 7.5 km, measuring values between 11.2 and 13.9 m a.s.l. (±0.5 m). In all these areas the stage 5 marker has demonstrated its utility for tracing either areal and linear neotectonic movements.These results, that shown a feeble but clear tilting or the presence of active tectonic lines, contribute to the discussion about the possible role of hydro-isostasy in generating recent movements of the continental platform. At a first glance in fact, it seems that post st. 5 mobility in the investigated areas is more the effect of local tectonics than of a generalized loading and unloading process.

QUATERNARY AND HOLOCENE DIFFERENTIAL MOVEMENTS IN A MEDITERRANEAN COASTAL AREA (S. VITO LO CAPO - SICILY-ITALY)

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Within the SELFII Research Project on the sea level fluctuations in the Mediterranean an interdisciplinary study was focused on the quaternary evolution of a representative coastal area with the aim to evidence the relationships with the more recent tectonic local trends. The selected area (NW Sicily) was studied in the emerged and submerged zone, using jointly different sectorial approaches and doing direct geological and geomorphological surveys and numerical data interpretation. Inside the plain areas the present results show a series of marine terraces (locally associated with marine depositional and typical erosional features) with very high morphological evidence. These marine evolution traces, at the present dislocated under different elevation ranges (from about 90 meters to few meters above s.l.). were referred to the Middle to the Upper Pleistocene by stratigraphical considerations and direct absolute dating. Their longitudinal profiles show a different degree of deformation increasing in magnitude from the more recent forms to the older and clearly geometrically related with the N-S and NE-SW aligned tectonic regional trends. Some tectonic evidences are present in the more recent marine terraces as well as in the present beach deposits.

GEODETIC AND GEOLOGICAL MONITORING OF LONG TERM CRUSTAL MOVEMENTS IN THE THAMES ESTUARY AND GREATER LONDON

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Small ground movements can have major strategic or economic significance in the developed and developing world. An example of this is the growing concern about the effects of changes in ground level, in low lying river estuaries and coastal regions. The Thames Estuary and Greater London region exhibits these concerns warranting the construction of the Thames Barrier and other tidal defences.
This paper details a research project funded by the Environment Agency (EA) and the Natural Environment Research Council (NERC) in the UK, for the development and testing of a strategy for monitoring changes in regional ground level using high precision GPS and the ITRS, and providing an interpretation of such changes in terms of local and regional geology. The strategy is based around the use of a small number of continuously operating GPS receivers, acting as reference stations for a dense network of monitoring stations, observed using episodic GPS measurements. The strategy is being tested in the Thames Estuary and Greater London region, where a monitoring network has now been established, to facilitate the geological interpretation of the long term changes in regional ground level.
The paper will present details of the development of the monitoring strategy along with results from the first nine months of GPS observations.

FIRST RESULTS FOR CRUSTAL MOTION AND TIDE GAUGE POSITION VARIATION AT THE COAST OF SPAIN FROM THE SELF-II PROJECT

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In the framework of the SELF Project for the study of sea level variations around the Mediterranean the BKG with the support from the ROA conducted two GPS campaigns in Spain. In 1993 and 1996 five tide gauges and a number of intermediate stations were connected to the ITRF by five days of continuous observations. In the 1996 campaign two water vapour radiometers of BKG and ETH Zürich were installed at tide gauge stations. The data is analysed and the results are discussed in view of time dependent changes in position and height. The corresponding error limits for possible variations in the mean sea level as deduced from the tide gauge records are given. The analysis inlcudes a comparison of various solutions with and without the introduction of water vapour radiometer data at two points into the GPS analysis. The accuracy of the estimation of absolute heights versus the changes in relative height-differences along the Spanish coast is discussed.

KINEMATIC GPS FOR THE STUDY OF TIDAL UNDULATION OF FLOATING ICE TONGUES

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Kinematic GPS measurements have been made on some floating ice sheets and ice tongues in an area approximately of 100 km around Italian base in Antarctica. The vertical movement determined with GPS measurements has been in good accordance with tidal undulation obtained with tide gauge, taking into account the methods precision. Kinematic GPS measurements had the aim to study: - the effect of the floating mass on oscillation amplitude with the comparison between the results obtained with an antenna on the ice tongue and another one located on the ice pack in corrispondence of the first one. - the effect of ice thickness variation on ice tongue undulation from the ice front to the gounding ice zone - the tide behaviour in a relatively wide area (about 200 km) with observation carried in same time on different ice tonugues. The experiments can contribute , unitely to glaciological, geophysical and idraulic studies and researches, to define dynamic models of ice floating glaciers. This is fundamental for the evaluation of Antarctica glaciers mass balance and behaviour.

Recent vertical crustal movements of the northern shores of the Black sea and the sea of Azov based on geological, geodetic and tide-gouge data

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The area of study is the northern coast of the Black Sea and of the Sea of Azov, which is part of the Black Sea Plain, and (viewed geotectonically) part of the Scythian plate at the boundary with the Black Sea basin situated within the Alpine mobile belt. The area is about 850 km long and some tens of kilometers wide.Evidence from repeated leveling measurements (on 10 lines for the period 1916-1990) for the coast strip as a whole either do not show any movements or very insignificant subsidence (not more than 2 mm/yr) relative to the inner parts of the plain. Zones of contrasting movements have been identified. The rates in such zones are mostly 1-3 mm/yr, occasionally reaching 5-10 mm/yr during certain time intervals. The tide-gauge observations at 12 stations show subsidence at all coastal stations at rates of as much as 3-4 mm/yr, which is generally consistent with leveling data. In addition to a general southward tilting, geologic structural and geomorphological techniques revealed several nearly east-west flexural fracture zones, namely, in the lower reaches of the Dnieper (Bug liman), in the Perekop (northern Crimea-Sivash), and along the northern coast of the Sea of Azov. The geodetic, tide-gauge and geologic-geomorphic data are generally mutually consistent, providing evidence of recent coastal activity, regional and in separate zones.

SOME NEOTECTONIC INDICATORS IN QUATERNARY FORMATIONS OF THE NORTHWEST COASTAL ZONE OF PORTUGAL

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In the northwest coastal zone of Portugal (between the Minho river and the Serra da Boa Viagem/Mondego cape) some evidences of structural (overthrust, tilting), sedimentological (contorted bedding, slumping) and chronological (diachronous bedding) features have been detected during the last years, which seem to indicate the occurrence of neotectonic deformation in Quaternary deposits.
More recently, geophysical campaigns were initiated in order to locate the presence of tectonic accidents, that could be responsible for the observed field evidence. To complement the geophysics, some cores (till 40 m deep) were made at some points of the area.
Till now, just preliminary data are available. However, they confirm the post-Pleistocene neotectonic activity in the northwest coastal zone of Portugal.

RATE AND MAGNITUDE OF LATE QUATERNARY ISOSTATIC MOVEMENTS IN THE SOUTHERN NORTH SEA

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Holocene sea-level data from Belgium plot well above data from the western Netherlands due to differential (glacio- and/or hydro-)isostatic uplift. The rate of uplift decays from 2 m/ka at 9000 yrs. cal BP to less than 0.25 m/ka since 5500 yrs. cal BP, while the long-term tectonic movement is only 0.07 m/ka. The glacio-isostatic component of the uplift is probably related to the last phase of the collapse of a stationary glacial forebulge under The Netherlands and the Dutch and German sectors of the North Sea, in agreement with geophysical model results. Boundary values for the magnitude of isostatic uplift during the pre-Holocene period have been inferred from Late-Weichselian river gradient data, which give an estimate of the maximum slope of the land-surface on the southern (ice-sheet-distal) limb of the forebulge. They indicate that differential movement between Belgium and the Netherlands since 15 ka BP was not larger than about 30 m. These observations demonstrate that considerable isostatic movements occur over short distances (<150 km), even in areas relatively distant from former ice sheets in both space (southern North Sea) and time (early to middle Holocene). No single curve can be used as an appropriate model for the Holocene sea-level rise in the southern North Sea region as a whole.

NATURAL CAUSES OF RECENT (~100 yr) VERTICAL LAND MOVEMENT IN THE NETHERLANDS

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Geodetic leveling data document differential vertical movements of the top of the Pleistocene sands of up to 1.5 mm/year in the Netherlands over the last century. We have compared these movements to: (a) mean tectonic, isostatic and compaction movements at time scales of millions of years obtained by backstripping; (b) estimates of recent (~ 100 yr) movements from process modelling of glacio-isostasy and compaction. The former are insufficient to account for the geodetic observations by an order of magnitude. The latter can explain less than half of the observed movements. This suggests that the residual - observed less isostasy and compaction estimates - which is interpreted to represent tectonic crustal deformation, constitutes an important contribution to present-day movements. The results suggest that correction of tide-gauge records for the glacio-isostatic signal alone does not yield an appropriate measure of eustatic sea-level rise in this area.

RECENT VERTICAL CRUSTAL MOVEMENTS IN POZZUOLI, PHLEGREAN FIELDS CALDERA, SOUTHERN ITALY

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SESSION G2 : P. A. PIRAZZOLI - Preference for oral presentation

During the past 2000 years, vertical movements of several meters have occured in the active volcanic caldera forming Pozzuoli bay, near Naples (Southern Italy). Sea level biological indicators (traces of marine perforations) have been uplifted to 7 meters above present sea level on the three marble columns of the roman marketplace (temple of Serapis). It was granted that no marine shells remain on these columns (Dvorak and Mastrolorenzo, 1991). A recent survey disclose the occurence of several marine species *in situ* (*Lithophaga lithophaga, Mytilidae* sp., *Barbatia barbata, Irus irus* and *Vermetus* sp.). The coral *Astroides calycularis* was also founded at 7 m above present sea level, in a former marine cave, 1000 meters East of the roman marketplace (Rione Terra). Radiocarbon datation of this biological material is pending. These findings will give a better chronological accuracy on relative sea level variations of this famous site in order to confirm or deny classical Parascandola (1947) hypothesis of maximum subsidence during the X° century.

POSTGLACIAL SEA LEVEL HISTORY AND COASTAL TECTONICS

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The global viscoelastic theory of the glacial isostatic adjustment process which is based upon the use of a spherically symmetric and linear Maxwell model of the planetary interior has been shown to reconcile an extremely large fraction of the observed postglacial record of relative sea level change. This includes essentially all of the data from the "near field" of the ice-sheets, not only from sites that were once ice-covered but also from the surrounding regions of proglacial forebulge collapse. Although most data from the far field of the ice-sheets is also adequately reconciled by this model, there do exist data that have been construed to pose a significant challenge to the global theory. These consist primarily of the U/Th dated coral based records from the Huon Penninsula of Papua, New Guinea and from the Island of Tahiti. I will argue that the conventionally assumed rates of tectonic uplift that have been used to correct the data at these locations are significantly in error and will suggest that these rates should in fact be inferred so as to correct the misfits to the global theory that otherwise exist. I will also discuss a new set of data from of the east coast of Patagonia which reveal strong tectonic uplift effects to have been operative during Holocene time, presumably due to the subduction now occurring off the west coast of Patagonia..

Sea Level Change during the Last 2500 Years in the Kerch-Taman area (Black Sea and the Sea of Azov) Based on Data from Submerged Structures of Antiquity

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The low-lying Kerch-Taman area (the southern shores of the Sea of Azov and the northeastern shore of the Black Sea) is situated between the mountain structures of the Crimea and the Caucasus within the Alpine mobile belt of Europe. Intensive human settlement in the area during antiquity, starting in the 6th century B.C., and a satisfactory state of knowledge concerning archeological remains, including submerged ones, provide opportunities for estimating sea changes based on the positions of submerged archeological objects. In all, 15 submerged objects of the 6th century B.C. to the 4th century A.D. that had formerly been on dry land have been used. These are mostly haven structures, city walls, individual structures or their basements. At present they lie at depths of 2-4 m, corresponding to the total sea level rise during approximately the last 2,500 years. There emerges a differentiation in height changes for the shoreline ranging between 1.5-2.0 m and 3.5-4.0 m in accordance with the tectonic features concerned. Accordingly, the mean rate of sea level change inferred for the above time period is estimated as 0.6-1.2 mm/yr on the northern coast of the Kerch Peninsula and 1.0-1.6 mm/yr on the southern and eastern coast.

RESULTS OF THE SULAWESI 1997 GPS CAMPAIGN

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In October 1997, a dense geodetical network was measured with GPS in Sulawesi, Indonesia. The network is situated in a tectonic complex region near the triple junction of the Eurasian, the Philippine and the Indo-Australian tectonic plates. The GPS campaign included second repeat measurements, also for sites of the GEODYSSEA network in Indonesia and Malaysia and along a Palu-Koro fault transect in Sulawesi. Finally, co-location measurements were done at sites previously occupied by the Scripps Institution of Oceanography (SIO).
The acquired data, together with data from IGS stations in the same region, were analyzed at DEOS. Both the JPL GIPSY-II and the MIT GAMIT software were used to process the data. The DEOS 3D-Motion software was used for the network deformation analysis.
The results of this GPS campaign, obtained with 2 software packages, were compared to get an indication of the reliability of the solutions. Next, the station coordinates were processed together with those of the previous Sulawesi and GEODYSSEA campaigns of 1994 and 1996. A validated kinematic model for the present motions is derived, indicating steady state velocity or non-linear displacements. The tectonic motions are geophysically interpreted.

GLOBAL POSITIONING SYSTEM CRUSTAL DEFORMATION STUDIES IN THE LOWER TAGUS VALLEY AREA FROM 1994 TO 1997.

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The lower Tagus Valley is one the regions in Portugal with high seismic activity, where earthquakes of magnitude above 7 occurred in the past.
In 1993 we have established a Global Positioning System (GPS) 10-station network in order to determine crustal deformation in this area. GPS observations were subsequently carried out in 1994, 1995, and 1997.

In this paper, we present the main conclusions from the analysis of the three campaigns. The expected deformations for this area, as indicated by geological studies, are very small and therefore the displacements obtained from the analysis of these campaigns are still within the noise level of the observations. The most significant displacements we have obtained until now seem to be more related with monument instability and amount of water present in the soil than with tectonic deformations.

VALUE OF BIOLOGICAL INDICATORS TO DETECT RELATIVE SEA-LEVEL CHANGES : A GEODETIC CONFIRMATION

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It has been proposed that the study of fossil marine fauna can provide an up to 10 cm accurate estimate of the amplitude of relative sea-level changes, as well as evidence for episodic, usually seismic, vertical coastal movements. This result, based on biological and micro-geomorphological data, as well as on reports of historical earthquakes, can be confirmed by tide-gauge data, as our study in Nisyros (an active volcanic island in the SE Aegean) reveals. A quite unusual transient relative sea-level fall of about 25 cm, lasting for more than two weeks, was noticed by local people along the coasts of this small island and resulted in a massive killing of *Vermetus triqueteur* along a band 20-30 cm wide below the normal low tide level. Field studies and examination of recordings from the three nearest tide gauge stations in the area, at distances of 65-250 km, revealed that the observed relative sea-level fall was a transient meteorological effect, unrelated to the series of earthquakes affecting or felt in the island during the preceding two years. Instrumental data, hence, confirm the excellent resolution and accuracy of certain biological sea-level indicators to detect and describe the amplitude and eventually the episodic character of relative sea-level changes.

PRACTICAL LESSONS FROM ANALYSIS OF A GPS NETWORK DESIGNED TO DETECT MOVEMENTS OF ≈ 1 MM/Y IN THE EASTERN PYRENEES

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Although the level of seismicity in the Eastern Pyrenees is currently moderate, with only one magnitude 5 earthquake recorded instrumentally, important earthquakes occurred there in the 15th century (1427-1428).
This straightforward observation suggests that the area is currently in the interseismic regime between large earthquakes separated by a long recurrence interval. In this case, strain may be accumulating as crustal deformation which we can measure by repeated geodetic surveys.
The geodetic network consists of 24 stations with a characteristic spacing of about 15 km. The monuments are concrete pillars anchored in bedrock outcrops chosen to span the traces of potentially active faults.
The network has been observed twice, in 1992 and in 1994, using dual-frequency receivers. The difficulties encountered and the experience gained processing the campaigns using the Bernese and the GAMIT software are described. For multi-epoch comparisons and velocity field determination, a new mathematical model has been developed as part of the GeoTeX software at the ICC. It yields results similar to those obtained by the GLOBK software. The lessons learned will allow us to improve the methodology and accuracy of future campaigns.

G3 Geophysical applications of radar interferometry

Convener: Massonnet, D.
Co-Convener: Feigl, K.

Sponsorship: CNES (Centre National d'Etudes Spatiales, France); CNRS (Centre National de la Recherche Scientifique, France)

SURFACE DEFORMATION MEASUREMENTS OF VOLCANOES USING SAR-INTERFEROMETRY

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Surface deformation measurements of active volcanoes using differential Synthetic Aperture Radar (SAR) interferometry could be extremely valuable. Volcanoes often deform prior to eruption, yet SAR does not involve the deployment of ground instruments, and thus poses no risk for field-crews. In this paper surface deformation measurements for Fogo, Cape Verde Islands, Popocatepetl in Mexico, Montserrat and for Unzen and Sakurajiima, Japan, are presented. We use the 'three-pass' approach, removing topographic signals with ERS tandem data.
For Popocatepetl a two-month interferogram has sufficient coherence for a deformation measurement over about 1/3 of the volcano's surface. On the SW flank of the volcano a 2000 m long phase signature can be identified, perhaps related to an eruption that occurred 2 days after the acquisition of the second scene. Fogo erupted in April 95. Several interferograms for the time period after the eruption indicate subsidence of an area covered by a lava flow . Subsidence was six month after the eruption at a rate of 3 cm/month and 12 month after the eruption at a rate of 1 cm/month. The subsidence is probably related to thermal contraction and to compaction of the cooling lava.

SAR INTERFEROMETRY STUDY OF THE M8.0 OCT. 9, 1995, JALISCO EARTHQUAKE (MEXICO)

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On October 9, 1995, the M8.0 Jalisco earthquake struck the western Mexican coast in the Manzanillo area. It is the largest event since 1932 along the Northern Central America subduction zone. This event is a shallow (17 km) thrust earthquake with a rupture plane shallowly dipping to the NE, related to the subduction of the Rivera and/or Cocos plate beneath Central America. It was well recorded by regional and worldwide seismic stations (Courboulex et al., 1997) and the associated coseismic deformation was measured by GPS (Melbourne et al., 1997). The inversion of seismological data shows that the rupture initiated 20 km offshore and propagated for 150 km in a N70W direction along a 9 degrees dipping plane whereas the inversion of GPS data shows that a variable slip model on a 200 km long plane dipping 16 degrees to the NE best fits the observations. Because this earthquake occured relatively close to the coast, the area of maximum expected coseismic subsidence is located onland and extends in a direction roughly parallel to the shore line. This makes the Jalisco earthquake particularly suitable for SAR interferometry. We present interferograms of the co- and post-seismic deformations associated with this earthquake. We discuss the constraints brought by this new data set on the rupture geometry and on the subduction processes at the Northern Central America subduction zone.

MODELLING THE DEFORMATION RELATED TO THE MW=8.1 ANTOFAGASTA EARTHQUAKE OF NORTHERN CHILE (1995) USING SAR INTERFEROMETRY AND GPS MEASUREMENTS

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The strong (Mw=8.1) subduction earthquake of July 30, 1995 ruptured the southernmost portion of the seismic gap of northern Chile. This gap, defined between 18°S and 25°S was covered by a GPS network of about 50 benchmarks installed in 1992 and remeasured after the event in 1995 and 1996. The exceptionally dry Atacama desert gives a good opportunity to study the surface deformation with SAR interferometry. To cover the large area deformed with ERS scenes requires to span at least 3 contiguous satellite tracks with 3-5 images (100x100 km) on each and to treat many interferometric couples. The interferograms show coseismic deformation over at least 150 km x 300 km reaching 60 cm of range increase. The asymmetry of the subsidence region, outlined by concentric fringes with an ear shape, is consistent with the right-lateral component of slip deduced from the GPS and body-wave inversion. We use the GPS and SAR data and an elastic dislocation model to explore in more detail possible source configurations and the evolution of deformation in time. The modelling procedure takes into account variable distribution of slip and possible geometric/kinematic complexities at the subduction interface. We discuss the consistency of the models with the seismic moment, the fault plane solution and the hypocenter of the mainshock and with the distribution of aftershocks.

MOISTURE EFFECT ON PHASE AND AMPLITUDE OF BACKSCATTERED MICROWAVE SIGNAL FROM SOIL SURFACES

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Early applications of RADAR techniques used only the amplitude and frequency of the backscattered signal in order to reconstruct position in space and to obtain basic information about targets. Actual radar systems give acces to the full information on the reflected electromagnetic wave, including its phase.
We discuss how phase and amplitude of the radar signal reflected by the surface of natural soil targets are influenced by the moisture content of the target. The purpose of this study is to get some hints on how information about phase and amplitude can be conjugated in order to retrieve moisture from radar measurements. The dielectric properties of the target depend not only on this average value, but also on how water is distributed inside, namely on the moisture distribution profile $m_v(z)$. Monostatic polarimetric measurements were performed, using the facilities of the European Microwave Signature Laboratory in Ispra, Italy, on different surface soils targets, within the frequency range (4 - 24 GHz).

SATELLITE RADAR INTERFEROMETRY IN THE SOUTHERN ICELAND SEISMIC ZONE: INITIAL RESULTS

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We attempt to apply satellite radar interferometry to the part of the Icelandic plate boundary where the seismic moment release rate is the greatest. Building on two previous studies which successfully correlated radar images acquired two years apart on recent lava flows, we analyze several image pairs spanning four years under favorable orbital and climatic conditions. To calculate the interferograms, we use the DIAPASON software developed by CNES and licensed via GDR INSAR. Depending on the magnitude of the vertical component of the deformation field, we expect between one-half and one interferometric fringe (3 cm) of range change in an interferogram composed of ERS-1 and ERS-2 images. We will attempt to interpret the interferometric measurements in the context of other geophysical measurements in this area which has been identified for particular scrutiny by the PRENLAB-2 project.

SATELLITE RADAR INTERFEROMETRY IN THE FRENCH ALPS: INITIAL RESULTS

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We attempt to apply satellite radar interferometry to the Belledonne range in the Northern French Alps. This area has been identified as currently undergoing rapid deformation on the basis of a comparison of GPS and historical triangulation measurements [Martinod et al., Geophys. J. Int., 127, 189-200, 1997]. According to these authors, the "data suggest a roughly 3-5 mm/yr active shortening concentrated at the external front of the Subalpine chains." Localized in a zone less than 100 km wide, such a velocity field implies a velocity gradient (strain rate) which reaches 4×10^{-7}/yr, among the most rapid deformation rates observed on the Earth's continental crust. If these estimates are indeed valid, the deformation should be detectable by satellite radar interferometry. Depending on the magnitude of the vertical component of the deformation field, we expect between one-half and one interferometric fringe (3 cm) of range change in an interferogram composed of ERS-1 and ERS-2 images acquired 5 years apart. The key question, of course, is whether the surface and climatic conditions will permit successful correlation over such a long interval of time. To calculate the interferograms, we use the DIAPASON software developed by CNES and licensed via GDR INSAR.

SURFACE DEFORMATION AT THE TJORNES RIFT-TRANSFORM JUNCTION (NORTH ICELAND) COMPUTED FROM SAR IMAGES

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The Tjörnes Fracture Zone (TFZ) is a diamond shaped transform zone between the offshore Koblensey ridge and the onland North Iceland Rift Zone. Its southern border is a 100km long N120°E dextral strike-slip zone, a few kilometers offshore North of the island for most of its length. Historically, it is a seismically very active segment with dextral strike-slip and normal mechanisms. Pull-aparts and pressure-ridges are characteristic of its onland section. The eastern tip is abruptly cut off by one of the fault zones of the North Iceland Rift Zone. Following the 1975 to 1984 Krafla rifting event, the seismic activity of the Husavik fault decreased considerably. It remained negligible for more than eight years. This change can be explained by a sudden stress increase, following the rifting episode, which would have blocked the fault. However, aseismic movement is not to be excluded.
SAR couples from ERS1 and ERS2 are used to form interferograms, covering the transform fault and its junction with the rift, with temporal values up to four years, across the transform fault. These observations will allow us to determine (1) the behavior of the transform fault after a major rifting episode, and (2) the local kinematics at the rift-transform junction.

DOES THE EFFECT OF POLLUTION AS ATMOSPHERIC INHOMOGENEITIES INTRODUCE PHASE SHIFTS IN SAR INTERFEROGRAMS ON URBAN SITES ?

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Ten interferograms of the city of Paris, France, are derived from tandem SAR images during the period July 28 1993 - Aug. 10 1996. For six of them, the use of a Digital Elevation Model to remove the topography is not required, as the baselines considered are small ($B < 30m$) on this area with low variation in elevation. The coherence is shown to remain high over more than 3 years, thus indicating the feasibility of the detection of very low subsidence rates over a long time span on urban areas. The main problem for this kind of measurements seems to be the tropospheric inhomogeneities and/or the pollution which could introduce phase shifts of the same magnitude of the signal we want to observe. Large scale phase variations as high as one fringe and located on the city can be easily detected on all interferograms. Those fringes can not be associated with topography, because of the small baseline values. This kind of " bubble " is even clearly visible on a 1-day interferogr! am, and excludes the hypothesis of a displacement which would correspond to a 3 cm subsidence of the whole city ! Using standard meteorological information and radiosoundings, as well as pollution data, the plausibility of these phase variations to be either atmospherical of origin or due to pollution is examined.

WHAT IS THE RESOLVING POWER OF INTERFEROMETRIC DATA TO CONSTRAIN SLIP DISTRIBUTION OF EARTHQUAKES AT DEPTH ? .

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Interferometry provides spectacular contour maps of the deformation created by earthquakes.
Is it possible to use such rich data set to constrain slip distribution of the earthquake at depth ?
Does SAR data (one component) provide additional information compared to GPS data (vector) ?
We applied two inversion techniques (genetic and least square) to SAR and GPS data of the 1992 Landers earthquake data separetly to test their uniqueness and resolution with depth and to compare their resolving power on slip distribution along faults. We also applied these techniques to "synthetic" data. We show that the use of interferometric data provides high resolution slip amplitude models, particularly at shallow depth.
In order to solve the problem of the lack of resolution at depth. we finally constrain the slip near the surface with geological observations and inverse the slip distribution at depth with SAR data.
These results are then used to constrain the rupture front velocity of the earthquake using strong motion data (see Cotton et al., this meeting)

LAND-SURFACE MONITORING USING INTERFEROMETRIC PHASE

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Radar interferometric data coming from remote sensing are multitemporal and display changes occuring between two successive acquisitions. As a consequence, interferograms contain significant information capable of enhancing land classification results. For instance, important phasimetric effects can be observed on some types of vegetation submitted to rainy periods. However, interferometric phase is less used for thematic monitoring. To draw the potentialities of these phase images for ground occupation study, it is necessary to detect and characterize meaningful structures.

In this work, we present a segmentation method for these structures which correspond to fields of same ground occupation. The segmentation of phasimetric artefacts is performed, taking into consideration the phase image and the interferometric coherence. The process is based on a statistical model, robust in a noisy environment.

The novelty of the approach resides on the use of two information (phase and coherence images) in order to correspond as close as possible to the effects' definition. The use of a statistical model provides good detections even for high perturbed areas. The model is easily extensible by using the radar intensity information and its temporal evolution.

INVESTIGATION OF THE MW=7.3 AQABA EARTHQUAKE OF NOV. 22, 1995 FROM SEISMOLOGY AND INTERFEROMETRY

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An earthquake of magnitude Mw=7.3 activated the southern part of the Levant fault system on Nov. 22, 1995. The epicenter was located offshore in the Gulf of Aqaba. Firstly a source model was derived from the analysis of teleseismic bodywaves and adjusted in view of the aftershock distribution, and surface ruptures observed in the fields. Coseismic deformation was determined using an interferogram computed from two ERS-1 SAR images with topographic corrections obtained from a digital elevation model (from SPOT stereographic views). The interferogram is used to derived a model of the dislocation which is compared to the model deduced from seismology, in order to assess the quality of the model proposed. Finally, the preferred model consists of three sub-events with a total duration of 18.5 s. and a general northward directivity. Fault planes strike between 10°E to 24°E with dip between 60° an 80°. Each sub-event is mainly strike-slip with a major left-lateral sense of shear and a minor normal component. They are arranged in a left-stepping en échelon fault system. We further discuss the significance of such event as to long term tectonic deformation, i.e. the geomorphologic development of the Gulf of Aqaba, and the 8 mm/yr left-lateral strike-slip motion along the Levant fault system.

SAR INTERFEROMETRY ON THE ST-PAUL DE FENOUILLET EARTHQUAKE (18 FEBRUARY 1996; ML=5.2; PYRENEES, FRANCE): SEPARATING ATMOSPHERIC AND COSEISMIC SIGNATURES.

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We use satellite radar interferometry to measure the coseismic deformation field produced by the Ml 5.2 St-Paul de Fenouillet earthquake in the French eastern Pyrenees. This earthquake occurred the February 18, 1996 on the St-Arnac Fault, in the Agly granitic massif, according to the detailed analysis of the aftershock sequence. Using ERS-1 and ERS-2 images, we calculate six interferograms of which four are coseismic over a period of 70 days, and two span a 1-day period for the tandem mission. All pairwise combinations of images correlate well despite marked differences in seasonal, climatic and surface (especially vegetation) conditions. The resulting interferograms exhibit a few 3 cm - fringes, not all of which are closed. These features cannot be the coseismic signal because of their location and their spatial dimension. Comparing the interferograms, we interpret these fringes as atmospheric artefacts related to local topographic reliefs in this area. After correcting these artefacts, we are able to extract the coseismic signal. Because the earthquake has a small magnitude and is located at 7.5 km depth, we are exploring here the limitations of the SAR interferometry technique. Nevertheless, these interferograms can help bound the depth and the mechanism of the earthquake.

G4 Precise satellite orbits for geophysical applications

Convener: Rothacher, M.
Co-Convener: Eanes, R.J.

PRECISE GPS ORBIT MODELING FOR GEODESY - REVIEW AND ERROR ANALYSIS

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In high-precision geodesy GPS orbits are estimated together with geodetic and geodynamic parameters of interest in a grand solution. Fixed to their estimated value, they can then be used to estimate many other geodetic parameters (e.g., as in point-positioning). In either case, orbital errors propagate to all other estimated quantities. For some quantities, such as length-of-day, GPS orbital errors can be a limiting error source. In the never ending quest to improve our knowledge of our home planet it is necessary to understand the limiting effects of GPS orbital errors on the accuracy with which we can estimate important quantities such as Earth Orientation parameters, site coordinates and tropospheric delay. In this paper we will review the state of the art in GPS orbit modeling and assess the level of orbital errors currently achieved. We will then present an error analysis in order to quantify the impact of GPS orbital errors on various geodynamic quantities. Finally, we will discuss the challenges and mysteries of GPS orbit modeling, and describe some present efforts and future prospects for improving GPS orbits.

IMPROVING THE FIRST HARMONICS OF THE EARTH GEOPOTENTIAL BY USING SLR DATA TO ETALON AND GPS SATELLITES.

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Taking into account that the orbits of Etalon and GPS satellites are located near the 2:1 resonance, we have carried out an improvement of the C_{22}, S_{22}, C_{32}, S_{32} coefficients which are the most influential coefficients of the geopotential for these orbits. We have used satellite laser ranging data to the Etalon–1,2 and GPS–35,36.
We have followed the IERS conventions as explained in the IERS Technical Note 21. We used the JGM–3 geopotential model and considered the perturbations due to the solid and oceanic tides, lunisolar attraction, solar radiation pressure, Earth rotation, apparent forces, indirect oblateness, tropospheric corrections, oceanic loading and plate displacement. To carry out our work, we have made use of a version of the ORBIT10 software adapted to these satellites and SLR data.
Values obtained for the above mentioned tesseral coefficients improve the values of the model in the last significative digit, and maintain the same approximation to the global model. The results obtained for the Etalon satellites gave smaller residuals than for the GPS satellites.

ON GFZ-1, DIADEME-1C AND DIADEME-1D ORBIT AND GRAVITY FIELD MODELING

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The GFZ-1 satellite is orbiting the Earth since April 1995. Its altitude declined from the initial height of 400 km to now under 380 km. While its altitude is continuously decreasing, its sensitivity to the Earth's gravity field is simultaneously increasing. Thus, gravity field modeling remains the primary mission goal during its entire life of up to five years.

Evaluation of GFZ-1 laser tracking data has resulted in a new satellite-only gravity field model based upon the PGM055 solution deduced from 34 other satellites. The sensitivity analysis of the new model shows that the incorporation of GFZ-1 data has contributed to an improved estimation of the harmonic coefficients in the GFZ-1 resonant orders 31 and 46 as well as to the evaluation of harmonic coefficients in the resonant orders 61, 77 up to degree 100.

The recently retracked satellites Diademe-1C and Diademe-1D are relevant for gravity field modeling due to their low inclination orbits at about 40°. New gravity field models have been determined also on the basis of the PGM055 satellite-only solution by incorporation of the new laser data acquired during the period of April to October 1997. Significant improvements can be seen not only in the resonant orders for both satellites, but also inbetween the resonant orders due to the low inclination impact.

ANALYSIS OF THE PRECISE RANGE AND RANGE-RATE EQUIPMENT (PRARE) AND IT'S APPLICATION TO PRECISE ORBIT DETERMINATION

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This presentation will show the impact of the Precise Range And Range-rate Equipment (PRARE) on the quality of the orbits produced for ERS-2. The addition of PRARE data allows the orbits to be computed without using the satellite altimetry, which prevents aliasing of oceanographic signals into the orbits. The PRARE system provides range and Doppler measurements from a widely distributed network of ground stations. In addition to PRARE, Satellite Laser Range (SLR) measurements are also used in the orbit determination procedure. The PRARE network complements the network of SLR stations tracking ERS-2, with many PRARE stations located in the Southern hemisphere. The PRARE/SLR orbits are evaluated by using the altimeter crossovers as an independent measure of their accuracy. Other methods of orbit evaluation include: comparing orbit height differences between independently determined orbits, comparisons between sea surface topographies computed from ERS-2 and those obtained from TOPEX/Poseidon, and examination of arc overlaps. The estimates of the PRARE station coordinates will be evaluated by examining the consistency of solutions over different time spans, making comparisons to externally computed coordinates, and comparing the results to survey ties to other well known geodetic monuments. The results of using the PRARE data to tune the gravity field will also be presented.

PRECISION ORBIT DETERMINATION OF THE TROPICAL RAINFALL MEASURMENT MISSION USING TDRSS WITH APPLICATION TO GEOPOTENTIAL MODEL IMPROVEMENT

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The Tropical Rainfall Measurement Mission (TRMM) was launched on November 27, 1997, into a 340 km orbit at an inclination of 35 degrees. This altitude and inclination represent an undersampled combination in recent satellite-only geopotential models. Primary tracking and telecommunications for TRMM are being provided by the Tracking and Data Relay Satellite (TDRS) System (TDRSS), which supplies one- and two-way range and range-rate tracking data to user satellites. Application of enhanced force and measurement modeling, the precise orbit knowledge of TOPEX/POSEIDON and it's TDRSS tracking, along with the leveraging of TDRSS tracking of other satellites is used to reduce TDRS orbit errors. The increased accuracy in the TDRS orbits, in conjunction with improved spacecraft force and measurement modeling, allows the strength of the TRMM tracking data to be used for geopotential model improvement. Results of the TRMM orbit determination for the first two months of the mission will be presented, in addition to an assessment of it's impact on satellite-only geopotential models.

A short arc orbit method for altimeter satellite with laser reflectors

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Because of their truly global coverage and direct tie to the geocenter through the satellite tracking stations, satellite altimetry should be the technique that provides the best measurements of the global sea level change over the shorter averaging periods. According to is of interest for ocean dynamic studies and for the accurate assessment of the current rate of change of sea level, to find out with the best possible accuracy the radial component of the position vector of an oceanographic satellite, like TOPEX-POSEIDON, ERS-I or ERS-2, with an altimeter on board. According to we present in this communication the short arc orbit computation method we have developed including the criteria, characteristic and budget error. The main features of our technique consist of a detailed "a priori" analysis of the geometrical shape of the passes with respect to the laser stations, to have the best orbit component determination over an orbit of 3000-4000 km. Our method takes as reference the Precision Orbit Ephemeris(POE) computed by NASA for each Topex-Poseidon ten days repeats cycle.POE orbits are accurate, in its radial component, better than 4 cm.Our short arc formalism computes corrections to this input orbit, when the satellite overflies the European laser tracking net, typically 10 to 15 minutes, covering an orbit length of about 4000 km.The tracking data used were the normal points at the frequency of 15 seconds intervals, as produced by EUROLAS data Bank for its public use.Results obtained are compared with NASA, CNES and CERGA orbits and an "a posteriori" analysis is made using our orbit and the SLR tracking residua.

VERTICAL RATES OF THE DORIS STATIONS

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The DORIS space system allows determination of 3-D station velocities. Here we present vertical motions of 48 globally distributed DORIS stations based on 4 years of data on SPOT-2, SPOT-3 and Topex-Poseidon. Although the time span of data is still short, 36 out of the 48 stations have vertical rate formal errors less than 1 mm/yr. Except for those stations subject to significant postglacial rebound, hence of predictable vertical motion, most DORIS-derived vertical rates can hardly be validated. In some cases, however comparisons with SLR, VLBI or GPS-based vertical rates have been carried out. In addition to the linear trend, short term (mostly seasonal) variations in the vertical component of many stations are reported. Possible sources of the observed seasonal variation are investigated.

SUB-CENTIMETER LAGEOS ORBIT DETERMINATION: TECHNIQUES, MODELS, AND APPLICATIONS

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Many of the scientific applications of space geodesy observations depend upon the determination of tracking station and satellite positions with accuracies of a few millimeters or better. Examples are: maintenance of an accurate terrestrial frame to support studies of sea level using satellite altimetry; measuring the anelasticity of the solid Earth from its effect on station positions, satellite orbits, and Earth orientation; and monitoring of the mass distribution and relative angular momentum of the air, water, and ice in order to provide global scale constraints on general circulation models applied to climate research. Satellite laser range observations of Lageos-1 and Lageos-2 have sufficient accuracy and spatio-temporal resolution to address many of these demanding applications providing that state-of-the-art a priori physical models are used together with appropriate orbit determination and parameter estimation strategies.
This paper will explain the orbit determination and parameter estimation techniques used to compute station positions and Lageos-1 and Lageos-2 orbits over a five year span which fit the satellite laser range data to an RMS of 7.5 mm. The results of applying this SLR data to the determination of the vertical component of station velocities, tidal and low frequency variations of earth orientation and geocenter motion, and orbital perturbations caused by solid earth anelasticity and the motion of the geophysical fluids will be presented. These results establish the adequacy of the orbit determination techniques currently used and suggest improvements which will be implemented in future studies.

IMPROVED EARTH GRAVITY SOLUTIONS DERIVED FROM TDRSS TRACKING

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Satellite-only solutions for the gravity field of the Earth have traditionally been deficient in data from low altitudes and inclinations. We have been experimenting with updates to the satellite-only solution EGM96S using new Tracking and Data Relay Satellite System (TDRSS) data from the Compton Gamma Ray Observatory (i=28.5°, alt.=380 km), the Rossi X-Ray Timing Explorer (i=23°, alt.=579 km), the Earth Radiation Budget Satellite (i=57°, alt.=585 km), as well as additional data from the Explorer Platform/Extreme Ultra-Violet Explorer (i=28.4°, alt.=510 km). The inclusion of these data is made possible through the application of improved orbit determination and modeling for the TDRSS relay spacecraft. We have tested the addition of these data to a new satellite-only model and found that the variance of the comparison with the independent 5° GEOSAT altimeter-derived gravity anomalies has improved to 9.32 mGal^2, compared to 10.19 mGal^2 with EGM96S, and 16.35 mGal^2 with JGM-2S. We will describe the contribution of these TDRSS data, as well as the data from the recently launched Tropical Rainfall Measurement Mission (i=35°, alt.=340 km), in satellite-only Earth gravity solutions, and in combination solutions with direct altimetry and surface gravity.

THE MOTION OF THE PRARE-STATION NEUMAYER LOCATED ON A FLOATING ICE-SHELF IN ANTARCTICA

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The Precise Range and Range Rate Equipment (PRARE) on board of the European remote sensing satellite ERS-2 is primarily used for orbit determination and ionospheric modeling. Additionally, it is possible to determine the position of any ground station within the network of global PRARE- and laser tracking stations with an accuracy of better than 2 cm.

Since January 1996, the PRARE ground station of the Alfred-Wegener-Institut (AWI) located on a floating ice-shelf in Antarctica is tracking about 12 ERS-2 passes per day. A detailed analysis of the tracking data yields a history of the motion of the station itself consisting of lateral and vertical components. The determined lateral motion of approx. 150 m per year matches a set of GPS measurements within a few cm. The derived partial tides are intercompared with those from ocean tide models.

Precise orbit determination for TOPEX/POSEIDON, The challenge, the history, and the impact.

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TOPEX/Poseidon has been the catalyst for recent improvements in precise orbit determination, and has led directly to the development of improved gepotential models from GEM-T1 through JGM-3, TEG-3 and EGM96. The achievement of orbits with a precision of 2-3 cm required that meticulous detail be paid to the attitude of the T/P spacecraft and the nonconservative forces that affect its orbit. The result is that T/P orbit determination has become the standard against which all other spacecraft missions, especially atlimeter missions from the ERS satellites, to GFO, to JASON have been or will be measured. This paper will review the latest activities in the field of T/P precise orbit determination, as well as the ramifications in geodesy and oceanography. Future improvements in the SLR, DORIS, and GPS systems, and the challenge of 1 cm orbit determination for the JASON will also be discussed.

SOME GEOPHYSICAL RESULTS FROM THE ANALYSIS OF ELEVEN YEARS OF LAGEOS1 DATA USING THE LINKING TECHNIQUE

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The so-called "linking technique" consists of linking dynamically short orbit arcs in order to generate a pseudo-continuous orbit over long durations, allowing the evaluation and analysis of geophysical parameters which produce long-term perturbations of satellite orbits.
In the framework of the first step of the GRGS/GFZ GRIM5 geopotential model computation, eleven years of Lageos1 orbit (1985-1996) have been recomputed using the linking technique over 10-day arcs.
Results include an evaluation of the movements of the Earth's center of figure with respect to the Earth's center of mass, modelled with a yearly bias, once per year and twice per year periodic terms ; the temporal evolution of the first zonal terms of the gravity field ; the computation of the coefficients of a few oceanic tidal waves which generate long-period perturbations ; and the determination of the position and velocity of tracking stations.

IMPACT OF INTERNATIONAL GPS SERVICE FOR GEODYNAMICS IN GEODETIC AND GEOPHYSISCAL APPLICATIONS

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The International GPS Service for Geodynamics (IGS) was officially established by the International Association of Geodesy on January 1, 1994. Its prime objective is to provide support and reference system for a wide variety of scientific and technical applications involving GPS. To fulfill its role, in addition to the fundamental products (orbital/station positions and consistent Earth orientation parameters) IGS also generates, or is about to generate, additional reference system products providing the necessary infrastructure, standards and means of calibrations for timing and various atmospheric applications of GPS. The generation and efficient use of IGS products and their impact on a number of positioning and atmospheric applications, including low earth satellites, will be reviewed and discussed.

ORBIT QUALITY REQUIREMENTS FOR SPACEBORNE ATMOSPHERIC SOUNDING USING GNSS

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The Global Navigation Satellite System (GNSS, presently GPS/GLONASS) enables active limb sounding of the Earth's atmosphere and ionosphere by placing GNSS receivers into Low Earth Orbits (LEO) and employing the radio-occultation technique. This method bears great utility for fields like operational meteorology, climate monitoring, and space weather, due to its potential to globally yield profiles of fundamental atmospheric parameters such as temperature and water vapor with quite unique vertical resolution (1 km or better) and accuracy (e.g., temperature < 1 K). A key requirement for gaining these data are high-precision orbits of the GNSS and LEO satellites involved. Currently, only rough quality requirement estimates are used (e.g., position: < 1 m (GNSS) and < 0.5 m (LEO), velocity: order of 0.1 mm/sec, timeliness for operational use: < 3 hrs). To provide more solid quantification, the impact of GNSS/LEO orbit quality on the accuracy of atmospheric profiles from occultations was studied within the rigorous framework of the "End-to-end GNSS Occultation Performance Simulator" software tool recently developed [cf. *Kirchengast et al.* abstract, session G9 "Atmos. Sounding with GPS"]. The results are presented and discussed with emphasis on clearly reporting the relevant needs of the "GNSS occultation" community to the "orbit modeling" community.

GPS-BASED PRECISE ORBIT DETERMINATION FOR ALTIMETRIC SATELLITES

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We describe recent advances in the determination of precise orbits for altimetric satellites using GPS data. The Topex/Poseidon (T/P) satellite, launched in 1992, carries a 6-channel GPS demonstration receiver (GPSDR). Dual-frequency (L1/L2) data from the GPSDR, collected when the GPS anti-spoofing (AS) function is not active, have been used to compute T/P orbits with RMS radial accuracies of 2 cm. We describe recent efforts to further improve the orbits derived from the L1/L2 data. These efforts emphasize reducing small errors in the centering of the orbit solutions in the terrestrial reference frame. With the routine activation of the GPS anti-spoofing function in 1994, the GPSDR has collected data primarily at the L1 frequency only. With RMS radial accuracies of 4-6 cm, next-day orbits based on these data have been used to support a variety of emerging operational oceanographic applications, most notably the monitoring of the 1997–98 El Niño event. We present in this paper strategies to improve the radial accuracy of the next-day T/P GPS(AS) orbits to the 3 cm level (RMS). Finally, we will include preliminary results of GPS-based orbit determination for the Geosat Follow-on (GFO) mission, assuming the data are available. Scheduled for launch in January, 1998, GFO will carry advanced 8-channel codeless GPS receivers. The GPS data are expected to support 2–3 cm RMS radial orbit accuracy independent of AS status.

IMPROVED PRECISE GPS ORBITS AT JPL

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Since June 1992, the Jet Propulsion Laboratory (JPL) has participated in the International GPS Service for Geodynamics (IGS), functioning as the IGS Central Bureau, an Analysis Center, a Global Network Associate Analysis Center (GNACC), and a GPS data distribution center. In the Analysis Center capacity, precise GPS satellite orbit solutions and earth orientation parameters are contributed on a weekly basis. Over more than 5 years, the accuracy of the JPL orbit solutions has improved from the 1-m level to the 10-cm level. While this improvement is due in part to the ever-growing ground network of GPS receivers, much of the increase in accuracy is attributable to the usage of better analysis techniques (e.g., carrier phase break insertion to deal with Anti-Spoofing, AS), geophysical models (e.g., tropospheric gradient estimation), and dynamic models (e.g., solar radiation pressure estimation). This presentation describes methods taken at JPL to realize improvements in GPS orbit determination, their impact on processing resources, and their influence on other estimated geodetic parameters. Prospects for further improved solutions and new products are also examined.

DERIVATIVES OF THE GRAVITY POTENTIAL WITH RESPECT TO RECTANGULAR COORDINATES AND APPLICATIONS

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We have recently derived very general formulas expressing the derivatives of the potential of arbitrary order with respect to rectangular coordinates (Métris et al, submitted to Celestial Mechanics; Métris, poster presentation proposed for this session). Each space derivative has the form of a spherical harmonics expansion similar to the potential itself. These formulas have several applications. In particular for computing satellite orbits strongly influenced by the gravity potential, we propose the following method in two steps: (i) for a given potential compute once the space derivatives of the potential up to a given order (e.g. 7) at points distributed in space (called main points), (ii) during the orbit computation, for a given point of the orbit, use the above quantities at the main point closest to the current point to evaluate the acceleration by means of Taylor series expansion. First tests have proved that this method is reliable and very efficient to compute short arcs (Métris, AGU fall meeting 1997). Here, we propose more extensive tests to explore the performances of this algorithm in various conditions (orbit, truncation degree of the potential, distances between main points...). Last, we also consider other applications of the Taylor series expansion of the potential like gradiometry or satellite to satellite tracking.

RAPID ORBIT AND ALTIMETER PRODUCTS FOR ERS-2

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Since July 1, 1997, the ERS-2 Rapid Products supplement the global products which are operationally generated at GFZ/D-PAF. These Rapid Products consist of the RPD (Rapid Orbit) and the ROPRs (Rapid Ocean Product Records), both on a daily basis with only 12 hours delay.
The near real-time orbit processing is possible due to the central data collection and preprocessing, and due to the continuously stable performance of the PRARE (Precise Range and Range Rate Equipment) tracking system on board of ERS-2. So, the RPD is also a useful tool to monitor the PRARE-specific range biases and the daily motion of the PRARE ground station Neumayer which is located on a floating ice-shelf in Antarctica.
The achieved orbit quality is of the order of 10 cm radially and, thus, allows the generation of the ROPRs with almost the same quality as the QLOPRs (Quick-Look Ocean Product Records). Ongoing improvements in the quality of the ROPRs, like the integration of daily global ionospheric maps derived from GPS, enhance the accuracy in real-time monitoring of ocean phenomena, e.g. El Niño.

STAR ACCELEROMETER IN-FLIGHT DYNAMIC CALIBRATION IN THE FRAME OF THE CHAMP GEODETIC MISSION

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The STAR-ONERA (France) accelerometer is going to fly on the CHAMP German satellite in 1999 with an unprecedented sensitivity of a few 1e-9 m/s/s. This instrument is based on the measurement of voltages between couple of electrodes enclosing a proof-mass in electrostatic suspension at the center of gravity of the satellite. The observed tensions are directly proportional to the surface accelerations acting on the satellite in 3 directions. At the altitude of the considered missions, below 450 km, such disturbing accelerations are not precisely enough modelled, while an accelerometer can observe them directly. This device will help improving the dynamic of the orbit and consequently the recovery of Earth's gravity field parameters. However instrumental biases originating in electronics, thermic and magnetic environment, proof-mass off-centering... will make necessary an elaborated in-flight dynamic calibration of the accelerometer to get its full performances. This presentation shows the strategy and the results of the STAR in orbit calibration using realistic simulated data in the frame of the CHAMP mission.

ECCENTRICITY EXCITATIONS OF LAGEOS AND LAGEOS-2

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Anomalous eccentricity excitations of the orbits of LAGEOS and LAGEOS-2 have been observed since launch, with especially large variations observed recently for LAGEOS. It appears that two phenomena are responsible for the major part of these orbital effects: (i) the Yarkovsky-Schach thermal effect, and (ii) a small bias in the mean radiation pressure coefficient caused by the correlation between solar radiation pressure and the Yarkovsky-Schach effect. The models for these surface force effects requires knowledge of the orientation of the satellite spin axis. The spin axis of LAGEOS-2 is currently assumed to be stable and known with some precision, but the evolution of the LAGEOS spin axis is uncertain. It can be shown that the very large eccentricity anomalies observed in 1997 can be explained by a significant departure of the spin axis from its predicted motion. It is concluded that determination of the temporal variations in the odd zonals and the odd degree tides is not possible in light of the uncertainties in the current models for these surface force effects.

IMPACT OF THE IMPROVED GPS ORBIT MODEL

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The Center for Orbit Determination in Europe (CODE) recently developed a new solar radiation pressure model for the GPS satellites. This CODE-model is purely deterministic and accounts for solar radiation pressure forces which are not modeled in the current ROCK-models. The most important difference between the CODE-model and the ROCK-model is a once per revolution term in the X-direction (X-axis is perpendicular to the Sun-satellite and solar panel axis directions). The CODE-model is a large improvement with respect to the existing ROCK-models. With the estimation of only two parameters, a (scale) parameter to account for the effect of the direct solar radiation and the so-called Y-bias, a 7-day arc fit, through the precise CODE ephemerides, using the ROCK-model gives an RMS of about 70 cm. With the CODE-model, estimating the same two parameters, the 7-day fit gives an rms of about 10 cm! Thanks to this improvement the number of parameters, which have to be estimated to model the behaviour of the GPS satellites, may be significantly reduced. CODE currently uses 21 parameters to model the GPS satellites over three days: 6 initial condition, 5 radiation pressure parameters, and 10 "pseudo-stochastic" pulses. We study which parameters no longer have to be estimated (or can be tightly constrained) and the impact such a parameter reduction has on other estimated parameters like e.g. station coordinates and Earth rotation parameters.

A NEW GRAVITY FIELD MODEL FOR THE ERS MISSIONS

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The radial orbit error has long been the major error source in ERS-1 altimetry, crippled by having only satellite laser ranging for precise tracking. Altimeter crossovers were successfully introduced as a tracking data type and the Precise Range And Range-rate Equipment (PRARE) provides a wealth of tracking for ERS-2. But the bane in ERS orbit computation remained the lack of sufficiently accurate general-purpose gravity field models.
DEOS developed a tailored gravity field model DGM-E04 based on crossover differences and JGM-3 as a priori model. The tailored model clearly outperforms any other available general-purpose gravity field models in providing accurate ERS orbits, especially in the radial direction. Yet, the SLR and PRARE tracking residuals clearly leave room for improvement. Therefor, a new gravity field model is constructed starting from a suitable a priori general-purpose gravity model and adding observation equations for SLR and PRARE and additional crossover data.
Various statistical tests on the ERS orbits and tracking and crossover data are analysed to establish measures for the orbit accuracy. The overall result is that the ERS orbit accuracy is about 5 cm in radial, and at the decimetre level in cross- and along-track direction. Verification tests on the behaviour of the model for other satellites like SPOT, TOPEX/POSEIDON, and LAGEOS show even slight improvements for these satellites.

A Detailed Modeling of the Solar Radiation Pressure Acting on Earth Satellites of Complex Shape

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In the last few years the weakening and deflection of the solar radiation through the atmosphere has been deeply investigated.
The model proposed combines both the geometric and physical causes of penumbra.The physical effects induced by the atmosphere on the solar radiation are treated by a purely empirical approach. The idea is to use the atmospheric data of extinction and deflection of the star-light which are usually collected during an astro-photometric calibration. These data allow the building of an empirical relationship of the atmosphere's extinction and deflection versus the height on the ground.
The strength of the approach is the simple mathematical and numerical implementation of the model and the possibility to perform, for every tracking session, the astro-photometric calibrations so described. In such a way we could be able to know the optical properties of the atmosphere all over the Earth in every day of the year. The model is applied to Earth satellites of complex shape like ERS-1 and ERS-2 .

PRESENT-DAY TECTONIC PLATE MOTIONS AND CRUSTAL DEFORMATIONS FROM THE DORIS SPACE SYSTEM

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DORIS data acquired between 1993 January and 1996 December from the Spot-2, Spot-3, and Topex/Poseidon satellites have been analysed to determine velocities for 45 sites on 8 major tectonic plates. For 28 sites far from deformation zones, the velocity estimates agree with plate model predictions. Least-squares computation of poles of rotation, which model the plate motions, shows that for Eurasia, Africa, Pacific and South America plates the agreement is better with Nuvel-1 while for Australia, Antarctica, Nazca and North America plates the DORIS Euler vectors are closer to Nuvel-1A. In general, DORIS results do not differ significantly from other space geodetic techniques determinations, but provide better estimates for plates poorly or inhomogeneously covered by GPS, VLBI and SLR networks, such as Africa. The DORIS coverage of this plate allows to discuss intraplate deformations due to the motion of the eastern Africa part which constitues the Somalia plate. Sites located in deformation zones such as western Eurasia boundaries, central Asia, western South America coast, South East Asia, show motion with respect to their own plates. Comparisons with other geodetic measurements for colocated stations, or with geodynamics hypothesis show the interest of DORIS in active zones where global geological models are not valid.

REGIONAL GPS ORBIT DETERMINATION

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The paper deals with the regional GPS orbit determination experiments conducted in our institute. Two Rogue data sets collected in 1995 and 1996 at four mainland stations(Shanghai, Urumqi, Changchun and Lhasa), one island station(Haikou) and additionally three nearby IGS stations(usu3,taiw,kit3) were processed using GAMIT/GLOBK. Two strategies for data analysis were used. First, all data of eight stations were jointly processed to produce the coordinates of unknown stations(Urum, Chan, Lhas and Haik) and the orbits of satellites with the coordinates of IGS stations tightly constrained. Second, the orbits were determined using the data only from Shanghai IGS station and four unknown stations whose coordinates had been obtained by first strategy.
For the purpose of comparison the 3-day and 5-day orbits were computed with spherical and Berne model used for the solar radiation. The derived orbits were compared with IGS precise orbits. The results showed that the daily repeatabilities of station coordinates are within 1 cm for northing and 2 cm for easting and height, and the accuracies of regional orbits were mostly better than 0.8 m. Also it is demonstrated that the 3-day orbits were better 5-day ones and the Berne model was better than spherical one especialy for 5-day arc.

G5 Ocean modelling from altimetry and remote sensing (co-sponsored by OA)

Convener: Knudsen, P.
Co-Convener: Le Traon, P.Y.

NORTH ATLANTIC SEA SURFACE VARIABILITY - A COMPARISON BETWEEN ALTIMETRY AND NUMERICAL MODELLING

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More than four years of satellite altimeter data from the Topex/Poseidon mission is used in combination with the EGM96 geoid to derive a series of more than 148 gridded models of the North Atlantic sea surface topography, each one representing a ten-day mean state. This series is used to constitute a long term mean topography and to study in detail the ocean variability in the North Atlantic by means of harmonic analysis and Empirical Orthogonal Functions (EOF).
For the same area, resolution and period of time corresponding topographies were derived by resampling the free surface heights of the Parallel Ocean Climate Model (POCM) of Semtner & Chervin as kindly provided by Dep. of Oceanography, Naval Postgraduate School, Monterey.
The differences between both topographies, the altimetric estimate and the oceanographic model were analyzed with respect to both, the geographical and temporal distribution. It is shown how strong the series are correlated and how well the agreement is for the dominant periodic and aperiodic oscillations.

TOPEX-POSEIDON DATA ASSIMILATION IN AN OCEANIC GENERAL CIRCULATION MODEL OF THE TROPICAL ATLANTIC

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TOPEX/Poséïdon and ERS-1 altimeter sea level anomalies, eXpendable BathyThermograph temperature profiles, Sea Surface Salinities and Temperatures have been assimilated into a non-linear primitive equation model of the tropical Atlantic ocean during 1993-1994. The results are analyzed by comparison with reference data sets such as the CITHER 1 data set. The emphasis is on thermal, salinity and current structures in the upper layers of the tropical Atlantic. Analysis of transports has also been conducted, especially in the North Equatorial CounterCurrent area.

APPLICATION OF TOPEX/POSEIDON ALTIMETER DATA FOR CEOF AND ALONG-TRACK ANALYSIS IN THE EASTERN ATLANTIC OCEAN AND WESTERN MEDITERRANEAN SEA

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Some global and regional applications to mean dynamic topography, ocean variability and sea-level anomalies are showed using a developped software to process TOPEX/POSEIDON MGDR Altimeter data.
Complex Empirical Orthogonal Functions (CEOF) technique has been applied in sea-level anomalies maps. This technique separates the variance into spatially and temporally uncorrelated modes of variability. Amplitude and phase modes are computed in the San Vicente Cape geographical area (Longitude: 12-18°W, Latitude: 33.5-36.5°N). The first mode represents the 65% of the total variability. The greatest values are associated with the peaks of the variability of the Sea Surface Height, SSH. The second mode represents the 17% of the total variability, indicating that the area is dominated by these two first modes.A collinear, along-track, analysis in an ascending track in the Western Mediterranean is made to show the influence on the SSH caused by ocean tide components. Interpretation of spectral analysis is also discussed.

ASSIMILATION OF TOPEX POSEIDON AND ERS ALTIMETER DATA FROM 1993 TO 1998 IN THE NORTHEAST ATLANTIC

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In the context of the SOPRANE project, we have developped an assimilating model whose aim is to provide real-time operational ocean products including analysis and forecast. This model is derived from the SIMAN model (Blayo et al 1994) and the SOFA optimal interpolation scheme (De Mey 1994). This model covers the Northeast Atlantic from 24° to 54°N and from 35°E to the European/African coast. It features 10 levels on the vertical and a 1/10° horizontal resolution. The assimilation of altimeter data is performed through the succession of 1-week assimilation cycles during which surface altimeter data are assimilated in a model reduced state by optimal interpolation. The full state correction is then computed using the vertical EOF extension scheme first introduced by De Mey and Robinson (1987). A simple - non evolutive - error covariance propagation model is implemented. We have assimilated GDR TOPEX POSEIDON and OPR ERS 1 and ERS 2 altimeter data during the period from 1993 to 1998. The results obtained in the Azores/Canaria domain are discussed in terms of dynamical properties and seasonal variability of the currents. The impact on the assimilation results of the altimeter data processing which is performed prior to the assimilation is also discussed.

A STUDY OF THE SOUTH-EAST INDIAN OCEAN VARIABILITY FROM ALTIMETRIC, WIND AND XBT DATA.

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We investigate the seasonal and interannual sea level variability in the South-East Indian Ocean from Topex/Poseidon altimetric data. This region is important for climate studies, in relation to the interannual variations of the tropical oceans and atmosphere. The eastern Indian region is directly affected by the strong seasonal monsoons. The Indonesian throughflow between the Pacific and Indian Oceans provides another forcing. As a result, the dynamics of the south-east Indian ocean are unique, with a very large mesoscale variability off western Australia. This eastern boundary is the likely generating region for the westward propagating Rossby waves observed in the subtropical band. These waves affect both the ocean dynamic height and sea surface temperature. In order to explain part of the observed sea surface variability, we use the vorticity equation with the low-frequency quasi-geostrophic assumption to calculate the sea level response to local wind forcing or remote forcing from the eastern boundary. We use ERS-1 scatterometry for the wind forcing; eastern boundary conditions are given by XBT data. First results indicate that significant correlation exists between the calculated variability and sea level variability observed by T/P. A comparison with numerical model output will also be discussed.

THE 1996 SEA SURFACE HEIGHT ANOMALY OF THE NORTH ATLANTIC SUBPOLAR GYRE

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A sea surface height time series from the TOPEX/POSEIDON altimeter data as provided by AVISO's corrected sea surface heights (CORSSH), was taken to investigate sea level anomalies in the North Atlantic. The period from 1992-1996 was used to perform a long term Mean Sea Level (MSL). Comparing this MSL with annual and seasonal mean fields an anomalous sea surface height feature could be significantly identified for the year 1996. This anomaly becomes in particular clear, when periodic variations of the sea surface were identified and removed. The observed anomaly coincides with a drastic decrease of the NAO in 1996. Variations in sea surface temperature data (taken from AVHRR) and sea level pressure data (from NCAR/NCEP) were analysed by similar methods in order to investigate correlations between these data sets and to study the impact of the inverted barometer correction to the CORSSH.

MESOSCALE VARIABILITY OF CHLOROPHYLL AND SST IN THE CONFLUENCE OF THE BRAZIL AND MALVINAS CURRENTS FROM SATELLITE DATA.

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Subtropical convergence zones, as the confluence of the Brazil and Malvinas currents in the southwestern Atlantic ocean, are key areas for the global carbon cycle and climate since these regions act as large sink of atmospheric CO_2. This is due to the juxtaposition of the effect on pCO_2 of cooling of the southward Brazil current waters with the effect of the photosynthetic utilization of CO_2 in the northward flowing Malvinas current waters. This region is also a highly dynamic, energetic and complex area where remote sensing data can be powerful tools to investigate variability at various spatial and temporal scales. At the moment, there is very little known about the variability of phytoplankton distribution and its correlation with physical processes.
Our purpose here is to analyze the new colour data from the SeaWIFS and POLDER sensors to study mesoscale variability (10-300 km) at a daily frequency. We use those data in conjunction with other satellite data like infra-red sea surface temperature (AVHRR). From first analyses of preliminary colour data, we can observe areas of complex chlorophyll distribution (filaments and eddies) where the two opposite currents meet. We are using analytical techniques for the study of spatial patterns as autocorrelation function and principal component analyses (PCA).

MODELING WIND-FORCED SEASONAL-TO-INTERANNUAL VARIABLILITY OF SEA SURFACE HEIGHT IN THE NORTH PACIFIC

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The TOPEX/POSEIDON sea surface height data show a temporally and spatially varying response to wind-forcing in the North Pacific that appears to be a combination of freely propagating and forced Rossby waves. An isopycnal ocean model is used to investigate the role of the wind, stratification and topography in governing SSH fluctuations. The model is forced by seasonally varying winds; both with and without bottom topography. The spatial structure of the wave response is sensitive to the stratification as it influences the phase speed of the first-mode baroclinic Rossby waves. The topography has little influence on the wind-response south of 30N, where the first baroclinic mode appears to dominate SSH variations in the observations. North of 30N the barotropic mode is important, hence the topgraphy influences the solution. As in the observations, the model shows a seasonal modulation in SSH variability at mid-latitudes but not in the tropics, suggesting that local winds are important for forcing the wave response. In the model and the observations the SSH variability is larger in the western Pacific at mid-latitudes than in the eastern Pacific.

SATELLITE DATA ASSIMILATION IN THE OCCAM GLOBAL OCEAN MODEL

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As part of the european AGORA programme we have been assimilating TOPEX/POSEIDON altimeter data into the Southampton Oceanography Centre's high resolution ($\frac{1}{4}° \times \frac{1}{4}°$, 36 level) global ocean model (OCCAM). The assimilation method used is that of Cooper and Haines (1996), a dynamically based method which conserves water properties on isopycnal surfaces.
Results of a one-year, 1993, run of this model, driven by ECMWF 6-hourly winds and assimilating 10-day mapped TOPEX/POSEIDON data are presented. These results are compared firstly with results from the OCCAM model without altimeter assimilation. This way we can assess the impact of the assimilation both on the mesoscale processes and on the large-scale exchanges and transports. Secondly, the simulation is compared with independent datasets, particularly hydrographic data. These comparisons concentrate on three regions, Tropical Pacific, North Atlantic and the Southern Ocean.
Results of a method to improve the model mean sea level, particularly in the Gulf Stream and Kurushio separation regions, will also be shown.

EVALUATING SOUTHERN OCEAN RESPONSE TO WIND FORCING

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Winds over the Southern Ocean are among the strongest in the world, but the magnitude and variability of these winds is not well known. Because of the paucity of in situ measurements, Southern Ocean wind fields derived from numerical models have been notoriously suspect. New satellite wind measurements provide a more accurate means to estimate changes in wind forcing of the Antarctic Circumpolar Current. In this study, temporal variations in winds derived from the ERS scatterometers, from SSMI, and from the ECMWF forecast model are correlated with variability in Southern Ocean pressure and transport derived from the UK bottom pressure recorders in Drake Passage. Winds and bottom pressure measurements both show substantial variability on all resolved time scales. To extend the spatial coverage of the study, the winds are also compared with surface transport estimates reconstructed from Topex/Poseidon altimeter measurements. Finally the response of the ocean to wind fluctuations in data is compared with analogous quantities from ocean general circulation models.

THIRD-ORDER STATISTICAL CHARACTERISTICS OF WAVE FORMS IN RADAR REMOTE SENSING OF SEA SURFACE

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The problem of reconstruction of ripple energy distribution over large areas of sea surface from radar measurements is considered. The importance of the problem lies in the fact that the small-scale surface oscillations are sensible to weak surface flows, which, in turn, may reveal the nature of large-scale processes taking place in the sea depth.
The investigation of statistical properties of backscattering was performed by numerical simulation. An ensemble of wavy surfaces simulating sea-way process gives rise to an ensemble of corresponding backscattering amplitudes, and the statistical characteristics of the two ensembles are considered. It is found that the sea-way spectral energy distribution, taken alone, does not provide enough essential characteristics to describe statistical properties of backscattering. New quantitative characteristics of skewness of wave peaks, ripple localization etc. are based on bispectrum — third order statistics of the surface elevation.
The results show that it is the small-scale wave form peculiarities that may account for some fine backscattering properties, e.g. upwind-downwind asymmetry. Thus the large-scale waves may be treated as independent, whereas the nonlinear consideration for small scales is necessary. The possible improvement of existing statistical model of sea surface is discussed.

ALTIMETER-BASED REFINEMENT OF TURBULENT DIFFUSION COEFFICIENTS

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One of major factors responsible for ocean transport of heat, salt, and bio-geochemical quantities is the horizontal turbulent diffusion caused by "sub-grid" variations of ocean current velocity. Using a recently developed technique of altimeter data analysis, statistical characteristics of the slow, i.e. vortical component of ocean dynamics can be derived from the sea surface height (SSH) field. Vortical motions are responsible for horizontal turbulent diffusion on large scales, and Richardson-type relationships allow expressing the diffusion coefficient in terms of energy and enstrophy spectral fluxes in 2D turbulent cascades. We demonstrate how these fluxes can be estimated and the coefficients of horizontal turbulent diffusion refined based on appropriate statistical characteristics of SSH variations.

RESIDUAL ERRORS IN DUAL-SATELLITE CROSSOVER ALTIMETRY DATA: AN INDEPENDENT CHECK

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Typical lifetime of an altimetry mission is five years. Dual-Satellite Crossovers (DSCs) have been recognize as a useful tool to interconnect two or more altimetry missions to provide oceanographers by long-term series in a unified system with the same "geodetic constants" to avoid any misinterpretation of the data. One obstacle to create such series comes from different realization of geocenter of various altimetry orbits. It was revealed by means of the DSCs, using the JGM~2 and JGM~3-based orbits (with up-to-date environmental, empirical and other altimetry corrections) that there is statistically significant geocenter offset between Geosat and T/P. We can provide oceanographers by corrected DSCs of Geosat - T/P for 1986-1996. To increase confidence in our results, we performed various tests, including use of specific *combinations* of the DSCs. The formulae and method have been worked out in Ondřejov and tested with data from Silver Spring. Recently, GFZ has been asked for a check. The DSC long-term averaged residuals and their combinations were computed independently in GFZ, Oberpfaffenhofen and compared to results from NOAA, Silver Spring. The DSC residuals are a composite of non-perfect media, 1 cpr empirical, tidal and other corrections. These effects are estimated by a new diagnostic method (developed in Ondřejov) based on the DSC combinations.

VELOCITY AND TRANSPORT OF THE LABRADOR CURRENT DETERMINED FROM ALTIMETRIC AND HYDROGRAPHIC DATA

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TOPEX/POSEIDON altimeter data from 1992 to 1996, in conjunction with hydrographic and meteorological data, are analyzed to examine currents and transports in the Labrador Sea, with an emphasis on seasonal variability of the Labrador Current. Based on the linearized momentum equations, vertically integrated velocities and transports on selected sections across the Labrador Sea are computed. The seasonal range of the Labrador Current transport from the shelf break to the 2500-m isobath varies from 17 Sv at the Nain section, to 6.5 Sv at the Hamilton Bank section and 5 Sv at the northern Newfoundland section with maximum in winter and fall and minimum in spring. Horizontal density gradient and sea surface slope have comparable contributions to the seasonal variability. In comparison, the contribution of the Ekman transport forced by local wind stress is much smaller. Except for the Nain section, the seasonal variability in the lower continental slope is weaker than that over the shelf break and upper slope. An exploratory study of the absolute mean transport of the Labrador Sea is carried out using available geoid data. A mean transport of 23 Sv in the Labrador Current (shoreward of the 2500-m isobath) and a basin-scale transport of 50 Sv in the Labrador Sea are obtained, consistent with Reynald et al.'s (1995) results.

An integrated system for handling, analysis and visualization of ocean data

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"Busstop", an integrated system for handling, analysis and visualization of ocean data, is presented. Busstop integrates functionality typically found in Geographical Information Systems (GIS), image processing systems and data base management systems, and provides a smooth interface to user written programs. The traditional spatial GIS functionality has been extended with transparent support for temporal data as well, enabling the GIS functionality to work even as a tool for analysis of dynamic phenomena. The Busstop data model integrates point data and grid data in a more general model, which is useful for combining satellite altimetry with ancillary data on gridded form. The visualization subsystem, called Reveal, provides functionality for static and animated visualization of gridded data, and combined views of gridded and point data. Additional analytical and data handling functionality is currently being developed. Proof-of-concept studies, carried out using the PC based prototype version of Busstop, has included studies involving combination of satellite altimetry with atmospheric model data, sea surface temperature data, gravimetry and airborne altimetry. Additionally, the system has been used for explorative visualization in case studies involving SAR scenes, and output from an ocean tide model. Busstop has shown very useful as an integrated and integrative platform for multidisciplinary ocean studies.

SYNTHETIC GEOID FOR MESOSCALE STUDIES OF THE AZORES CURRENT

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The SEMAPHORE-93 mesoscale air/sea experiment took place in the Azores front/current domain from June to December 93. About 40 ARGOS-tracked surface drifters, drogued at 150 m depth were deployed and three hydrological arrays were performed. Moreover, ERS-1 and TOPEX/POSEIDON (T/P) were flying at that time. The altimetric data were processed using the collinear passes method, as part of the CANIGO project. They are in excellent agreement with in-situ measurements. The comparisons with dynamic height fields objectively mapped from XBT/CTD casts show 4-5 cm rms differences. Also, comparisons with drifter velocities close to the satellite ground tracks exhibit 7-9 cm/s rms differences. But because of the lack of a precise geoid the total ocean circulation cannot be inferred from satellite altimetry. Thus, SEMAPHORE data are combined by multivariate objective analysis to provide maps of the surface circulation. Then, over 6 months, the differences between altimetric and in-situ maps are used to build a synthetic geoid in the area. Based on this reference field, the Azores current circulation is monitored from 1992 to 1997 using ERS-1, ERS-2 and T/P data.

HIGH RESOLUTION MEAN SEA SURFAES FROM MULTI MISSION SATELLITE ALTIMETRY

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Satellite altimetry from the GEOSAT and the ERS-1 geodetic missions provide altimeter data with a very dense coverage. Hence, the height of the sea surface may be recovered very detailed. Satellite altimetry from the 35 days repeat cycle mission of the ERS satellites and, especially, from the 10 days repeat cycle TOPEX/POSEIDON satellite mission provide accurate mean sea surface heights along the ground tracks of those missions. In this study averaged sea surface heights of the repeat missions were used to construct an accurate mean sea surface. To enhance the resolution of the mean sea surface the altimetry from the geodetic missions was utilized. Marine geoid heights derived from the altimetric gravity was used for this task. The advantage of such a procedure is that inconsistences along the edges of the small cells may be avoided. The TOPEX/POSEIDON mean sea surface heights relative to the mean heights over 50 km are fitted by 2 cm and the slopes fit within a few mm per km.

GENERAL INVERSE OF A SHELF TIDE MODEL: APPLICATION TO THE M_2 TIDE IN THE BARENTS SEA

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When the general inversion is used to assimilate data into a model of a closed basin, a solution minimizes a weighted sum of square misfits in dynamic equations, the data, and a boundary condition at the coast. However, if the problem is solved for a shelf region, there is usually lack of quantitative information about the tides at an open boundary. Thus, to make the problem well-posed, we augment the cost functional with a regularizing term which penalizes large surface elevation at the open boundary. Then the science lies in the specification of the relative weights for different terms in the functional. Following our procedure, optimal weights for the data and the coastal boundary condition misfits would give a maximum to the sum of those terms (which reflect quantitative information). The weight for the regularizer (qualitative information) would be taken the biggest at which the solution is still not sensitive to its choice. The technique was used with a finite element model for the M_2 tide in the Barents Sea where in-situ and satellite altimetry data were both available. Although no boundary condition was assigned at the open boundary (for instance, taken from a global model), the rms deviation of the solution from surface elevation data not assimilated into the model was 4.4 cm which is much better then results obtained with other models.

SEASONAL TIDE VARIATIONS AND SHALLOW WATER TIDES FROM TIDE GAUGES AND ALTIMETRY

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TOPEX/Poseidon altimetry has during recent years greatly improved our knowledge of ocean tides. A remaining problem in ocean modelling, however, arises from the contributions of meteorological forcing, nonlinear coupling with storm surges and ocean circulation, and internal tides. Here we investigate the temporal variation of tidal solutions at tide gauges and as observed by altimetry, and try to identify its possible relation to the above effects.
nother challenge is to improve our models near coastal boundaries, where many existing T/P-based ocean tide models are inadequate due to the coarse spatial sampling and the additional presence of significant third- and fourth-diurnal constituents.
In a initial investigation for the North Sea, it was recently shown that T/P has the potential of improving our knowledge of even these near-boundary tides, such as M4, which may be as large as 20 cm. In this presentation we will extend our efforts in this area.
Additionally, we look at the potential of adding data from the ERS mission to further improve our altimetry-based results.

LARGE SCALE SEASONAL VARIATIONS OF ATLANTIC OCEAN BY COMBINING ALTIMETRIC AND HYDROGRAPHIC DATA IN AN INVERSE MODEL.

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An attempt is made to observe the response of Atlantic ocean from seasonal atmospheric forcing using an non-linear inverse model (Mercier, 1992). 3 years of Topex-Poseidon GDR (T/P, cycles 11 to 121), wind stress (ECWMF), and net heat flux (ECWMF, COADS) were combined with a new climatology built from NODC data (Reynaud, 1995). Inverse formalism allow us to ajust the velocities at the reference level, and the density field. Particular effort is made on heat conservation constraint where evolution terms (deduced from hydrograhpy, but also from altimetry) were added. A posteriori solutions give a good picture of the Atlantic general circulation between 20°S and 60°N. Heat conservation constraint has a strong impact in depth, implying seasonal variability of DWBC. Then, intensifcation of meridionnal overturning is find to bring heat from equator to northern latitudes during winter. Altimetric constraint is not useful when absolute dynamic topography deduced from T/P and EGM96 geoid is employed due to large errors in the geoid. Nevertheless, results with T/P sea level anomaly using in the model as a constraint on the anomaly of the surface dynamic topography are satisfying. Results, first demontrate consistency between seasonal anomaly of hydrography and altimetry data, and secondly, show that altimetric information is able to constrain surface circulation, especialy in tropics.

BIO-OPTICAL EMPIRICAL MODELS OF THE WATERS ADJACENT TO TAIWAN

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Optical properties of seawater in the waters adjacent to Taiwan area were measured by underwater spectroradiometer during four cruises from December 1996 to March 1997. Water samples were collected at the same time and analyzed for chlorophyll-a concentrations. Parts of the existing bio-optical models from SeaWiFS Bio-Optical Algorithm Mini-Workshop (SeaBAM) shown in Table 1 are used in this study.

The Diagnostic Analysis of Baroclinic Ocean Dynamics by Satellite Altimetry Data.

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The diagnostic analysis of ocean dynamics by satellite altimetry data may give complete hydrodynamical picture on that time moment, when appropriate measurements were made. The first valuation of baroclinic ocean dynamic structure can become definition barotropic (average on depth) mode of speed field, designed through integrated stream function on the basis of satellite information. As an initial system of offered model equations are considered equations of ocean dynamics in quasigeostophic approximation. The boundary condition on surface for vertical mode of speed fields is replaced by "firm cover" condition, and a condition of sliding without friction is at the bottom taken. For processing of satellite altimetry data, when the density field on whole ocean height is not known, is offered to search integrated stream function as anomalies from mean (mean season) significance. By virtue of it is possible to make the assumption that the changes of baroclinic layer thickness (in which are concentrated main density changes, and the which thickness is small in comparison with depth of ocean) are insignificant. In the first approach it is possible to consider, that the density anomaly concerning mean significance on a linearly change by vertical from surface significance to zero on the baroclinic layer bottom border. The account of dynamic topography on satellite altimetry data is carried conducted on mean sea surface field and geoid height. The model verification was conducted on independent data: satellite altimetry (ERM mission GEOSAT) and hydrological data (experiment NEWFAEXP-88 the program SECTIONS) for polygon Newfoundland Ocean Energy Active Zone in march 1988. In the first numerical experiment of dynamic topography anomaly was designed by hydrological data and simulated by self of satellite altimetry processing results. In the second initial information was considered directly by remote data from GEOSAT board. The mean fields of dynamic topography and integrated stream function were determined by known data file LEVITUS. The results analysis has shown, that integrated stream function fields and barotropic speed mode, received in result of imitation experiment, will be well agreed results of diagnostic accounts by density field. Thus, the offered model may with sufficient accuracy to define barotropic speed mode of baroclinic ocean by satellite altimetry data.

POLDER ON ADEOS: A NEW OCEAN COLOR DATASET TO COMBINE WITH ALTIMETRY

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With OCTS and POLDER the ADEOS mission is the first of a series of upcoming missions providing global Ocean Color datasets (SeaWIFS, EOS/MODIS, ADEOS2 with GLI & POLDER2). The POLDER (POLarisation and Directionality of the Earth's Reflectances) sensor is an imaging radiometer-polarimeter designed to measure the solar visible and near infrared radiation reflected by the Earth/atmosphere system. In addition to the classical measurements and mapping capabilities of a narrowband multispectral imaging radiometer, the POLDER concept has original polarization and directional capabilities which open new perspectives for sensor calibration, glitter rejection, atmospheric corrections and inversion of pigment concentration. Data have been acquired since October 30, 1996 till ADEOS loss on June 30, 1997. The calibration phase has been completed in May 97. The geophysical validation phase is ongoing, based on a dual strategy combining statistical approach and enhancement of in situ (atmospheric and oceanic) measurements networks.
Global results of POLDER marine parameters products and comparison with historical CZCS data will be presented. Potential applications in global biogeochemical studies include : i) the provision of synoptic fields of chlorophyll concentration to compare against the field derived from coupled, ocean-ecosystem models, -a comparison with a 3D modelling study in the North Atlantic will be shown- or to use for assimilating and/or initializing such models, ii) a basis for the computation of regional and basin scale estimates of primary production and iii) a generic vehicle for the extrapolation to large horizontal scale of small numbers of in situ discrete observations of various ecophysiological rates and pools. Correlation analysis with altimetry data will be illustrated in two subtropical gyres frontal zones, namely the Brazilian-Falklands Confluence zone and South African Convergence zone.

Abstract submission for EGS General assembly 1998

A variational assimilation model for the barotropic tides in a global ocean: principles and application to the long period tides

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The CEFMO model (Finite Elements Code for the Oceanic Tides) has been developed to produce high resolution solutions over the world ocean. In addition, an assimilation code has been developed to improve the solution accuracy by assimilating in situ and altimetric observations. It is based on a general inverse approach using the representers technique. One main characteristic of our assimilation approach is to formalize it as a continuous (i.e. not discretized) problem, leading to a pair of linear systems to be solved (adjoint and direct). Similarly to the hydrodynamic problem, they are treated under their variational formulation. First designed to solve the tidal problem on ocean basins, the hydrodynamic and assimilation models have been upgraded to produce global solutions where the inter-basin constraints are totally removed. A preliminary set of solutions for the main long period tides have been computed and validated. Our solutions show a very complex spatial distribution due to large wavelengths combined with small structures coming from the trapping of the tidal waves by the topography. The set of reliable observations, to be used in the assimilation, shows a poor density compared to the richness of the modelled spatial scales. Nevertheless, this application is an ideal test case to evaluate the robustness and the effectiveness of our modelling and assimilation approach.

LONG TERM MONITORING OF THE OCEANIC PRIMARY PRODUCTION SOUTH OF SOUTH AFRICA : USE OF THE REMOTELY SENSED DATA

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In order to better constrain the carbon fluxes in the southern ocean, the role of mesoscale eddies in biological production has to be elucidated in the large sink areas of the subtropical convergence zones. Causes of the variability of the phytoplankton distribution in relation to the forcing induced by the physical environment are studied in the eastern boundary current system of the South Atlantic ocean. The area of interest is the Agulhas current and its retroflection along with the upwelling area of the Benguela current. Remotely sensed data from POLDER and SeaWiFS for ocean colour are used in conjunction with other remote sensing data (SST, dynamical heights, surface winds) in the Agulhas/Benguela region. Standard statistical data analyses such as PCA and wavelets are applied to determine the nature of the temporal and spatial variability. As expected, phytoplankton variability shows correlation with the SST variability at the mesoscale. Correlation of ocean colour with altimeter data helps us reveal the underlying dynamical nature of the region. In the subtropical convergence (STC), a strong thermal gradient and an extended frontal area, created both by meandering Rossby wave of the ARC and eddies spawned at the STC lead to an increase of primary production. This enhancement occurs on a large oceanic area and then is of great importance in carbon fluxes estimation.

INTERANNUAL VARIABILITY IN THE EASTERN INDIAN OCEAN

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Interannual variability in the eastern Indian Ocean is investigated with the aid of Topex/Poseidon data, Reynolds SST data and a 10-year, monthly repeated XBT transect at the eastern boundary. The interannual variability in this region is influenced by local and remote wind forcing, and by the remote ocean forcing via the Indonesian Throughflow which allows interannual variations in the western Pacific to directly influence the eastern Indian Ocean. In addition, the south-eastern boundary includes the source of the annual westward propagating signal at 10°S and significant semi-annual Rossby wave activity between 20-35°S, which contribute to carrying the interannual variations from the eastern boundary into the ocean interior. The interannual signature in the mid-latitude propagating anomalies is apparent in T/P sea level anomalies (SLAs) and SST anomalies. Large-scale warm SST anomalies lasting several months also occur in the ocean interior, which coincide with the arrival of downwelling Rossby waves with positive SLAs, and possibly induce the observed upwelling-favourable winds which occur at the end of the warm SST anomaly.

TRACKING EDDIES IN THE SUBTROPICAL NORTH-WESTERN ATLANTIC OCEAN

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Anticyclonic eddies generated in the North Brazil Current (NBC) retroflection area are traced along the coast of North Brazil into the Caribbean Sea via altimetric SSH measurements by TOPEX/POSEIDON. At least 16 to 20 eddies can be seen to form in the NBC area during the period from October 1992 to June 1997, 12 of which can be followed into the Caribbean Sea, where they appear about one year after their generation. It takes them about 350 to 370 days to propagate from their formation area at about 5°N - 8°N and 315°E - 320°E into the Caribbean. Time scales of about 80 to 100 days, characteristic for the Caribbean, can already been found in the region of eddy formation. The observed eddy sizes range from 200 to 600 km. Their average amplitude is found to be about 15 cm, and their average propagation speed is about 14 cm/s. Thus, the connection of a continuous eddy path from the NBC area into the Caribbean, recently indicated by model calculations with a high-resolution (1/6°) ocean circulation model, has been shown to appear in the TOPEX/POSEIDON sea surface height anomalies.

APPLICATIONS OF HIGH ACCURACY ALTIMETRIC HEIGHT MEASUREMENTS IN ICE COVERED SEAS TO STUDIES OF THE POLAR OCEANS, AND COMPARISONS WITH MODELS

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The use of altimeter data in the polar regions has previously been restricted by the presence of permanent and seasonal ice cover. Changes in the radar echo shape received by the altimeter over sea ice, as compared with the open ocean, cause problems in the on-board estimates of surface height, resulting in a very noisy height signal. The majority of noise on the signal can be reduced by retracking the full waveform data set (WAP), but other factors have previously limited the noise reduction, most notably pulse blurring. Software simulation of the tracking system has led to the development of new ground processing algorithms, which further reduce the short wavelength (< 20km) noise, from 30-50cm, down to 5-10cm. This provides for the first time the capability for accurate mean sea surface generation and investigations into tidal and oceanographic signals in ice covered seas. The initial estimate of the rms variability of crossovers in the Arctic is 14-20cm, compared with a global average of 6-8cm. Sea surface anomalies are calculated over the Arctic Ocean and their potential in improving our understanding of tides and ocean circulation is explored through comparisons with existing models.

REGIONAL ANALYSIS OF THE INVERTED BAROMETER EFFECT OVER THE GLOBAL OCEAN

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Crossover sea level differences from TOPEX/Poseidon are regressed against atmospheric surface pressure, and the resulting latitude/longitude map of the regression coefficient is examined for deviations from the value of -1 cm/mbar expected for an inverted barometer (IB) signal. Such deviations can be caused by incidental correlations between measured atmospheric pressure and data errors or correlations between atmospheric pressure and dynamic sea level (i.e., sea level adjusted for an IB signal). Significant departures from the constant IB value are found in most regions, from the tropics to high latitudes. An ocean model is used to help interpret the observed IB departures and their spatial patterns in terms of the spatial characteristics of the forcing, the differences in regional dynamics and oceanic response to forcing, and the effects of wind-driven signals. Influence of high frequency signals, not well sampled by the altimeter, is discussed. The general validity of the IB approximation is assessed as a function of time scale and region.

SPACE-TIME VARIABILITY OF THE BLACK SEA GEOSTROPHIC CIRCULATION AS IT SEAN FROM SATELLITE ALTIMETRY.

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The Black Sea is a semi-enclosed sea with a strong seasonal variability of the sea level due to seasonal cycles of river runoffs, precipitation and evaporation. Both the ERS-1 and the TOPEX-POSEIDON altimetry obviously present the strong seasonal signal with the amplitude up to 25 cm that need to remove before the analysis of the surface geostrophic circulation. The altimeter data averaged along each track shows that the response of the offshore sea level to the water exchange is spatially uniform. It results from the barotropic nature of the response as well as from the fact that the size of the Black Sea is significantly less than the barotropic Rossby radius. The latter idea serves a basis of the proposed method of retrieving the anomaly of the Black Sea dynamical level, namely, the level, which reflects the surface geostrophic circulation. To obtain the outcome product the climatic sea level from the archive hydrology is added to the anomaly of the dynamical sea level from altimetry. The reconstructed dynamical sea level shows good correlation with the sea level obtained from the simultaneous CoMSBlack hydrology. The objectively mapped dynamical sea level is used to analyze a seasonal variability of the Black Sea circulation. The satellite altimetry manifests a well-known cyclonic Rim Current belting the Black Sea. The Rim Current has its maximum intensity in the winter-spring period. There is a break in the Rim Current beginning from the earlier summer. Simultaneously the mesoscale eddies occupy the basin. By the end of the fall the eddy activity weakens and the Rim Current recovers. Then the cycle repeats. Wintertime intensification of the Rim Current corresponds to the seasonal intensification of the atmospheric cyclogenesis over the Black Sea. The time-longitude plots of the sea level anomaly demonstrate the westward phase propagation. Thus the seasonal variability of the Black Sea circulation results from the seasonal variability of atmospheric forcing and the reflection of Rossby waves from the eastern coast of the Black Sea. The spectral analysis shows that mesoscale contains a substantial part of the total energy besides the seasonal cycle. The time spectrum clearly shows two periods of about 130 and 60 days. The eddy activity is the most prominent in the Rim Current vicinity. There are additional areas of the enhanced mesoscale variability in the westernmost part of the Black Sea, near the Bosphorus Strait, and near the bottom slope in the central part of the eastern Black Sea.

MECHANICAL ENERGY FLUX TO THE SURFACE GEOSTROPHIC FLOW USING TOPEX/POSEIDON DATA

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The rate of mechanical energy transfer from the atmospheric winds to the surface geostrophic velocity is estimated for the world ocean. The surface geostrophic velocity is calculated from the 4 year mean dynamic topography and the 10 day anomaly fields from the TOPEX/POSEIDON altimetry measurements. The wind stress is obtained from the NCAR/NCEP Reanalysis. An uncertainty estimate of the integrated energy transfer rate is more computationally demanding and therefore focused on just the North Pacific basin. The uncertainty is based on the geoid slope error estimates obtained from the JGM-3 geoid model coefficient covariance matrix. Despite the low signal to noise ratio, a meaningful signal can be extracted since the energy transfer calculation involves a projection of the estimated geostrophic current onto the wind stress field. The latter is more strongly correlated with the surface current than the geoid slope error.

MONITORING THE 1997/1998 EL NIÑO BY ERS-2

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The recent El Niño of 1997/1998 is one of the strongest in this century. With the radar altimeter and Along-Track Scanning Radiometer (ATSR) of ERS-2 this event was monitored in high detail. From the OPR-1 altimeter data, enhanced with Delft precise orbits, weekly "images" of the sea level anomalies are generated, each with an effective temporal resolution of 16 days (one subcycle of ERS-2) and with a fine spatial resolution of about 1.5°. Adding to this the ATSR sea surface temperatures, which are unfortunately hampered by cloud cover, we have an excellent set of data to study the evolution of the ocean dynamics in the Equatorial Pacific related to the El Niño Southern Oscillation (ENSO) from May 1995 onward. Animations clearly show the development of the latest El Niño. Especially the sudden Kelvin wave at its onset is clearly recognised as well as the fact that the event actually hits the American coast twice, in July and October 1997.
The altimeter data have been assimilated in a wind-driven shallow-water ocean model using variational and ensemble Kalman techniques. In this way we were able to bring the model sea surface elevations closer to the observations; the rms difference dropped from about 8 to 4 cm. Definitely, the incorporation of altimeter data improved our analysis and shows the potential of these data in ENSO dynamics research.

ASSIMILATION OF TOPEX/POSEIDON DATA INTO A SEASONAL FORECAST SYSTEM

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By assimilating T/P altimeter data into the oceanic component of a coupled ocean-atmosphere model we want to improve the seasonal forecast system at ECMWF. As a first step we compare gridded T/P data to results from the present forecast system in which XBT and TAO temperature obervations are assimilated into the ocean model via OI and SST is relaxed to Levitus. The mean value of the sea level for the years from 1993 to 1995 is subtracted from the model results and T/P anomalies are interpolated to the model grid. In general, both the mean annual cycle and the interannual variations agree quite well between observations and model results, including the onset and time-evolution of equatorial Kelvin waves and off-equatorial Rossby waves. There are spatial shifts of the anomaly-patterns however, and the T/P data show enhanced mesoscale activity. Amplitudes of the sea level are generally somewhat larger in the observations.
Thus, T/P data have the potential to improve oceanic initial conditions. Using altimeter data is not easy however. As a first attempt, T/P data are assimilated into the ocean model by locally adjusting the vertical density profiles as suggested by Cooper and Haynes (1996). Later efforts will include the combined assimilation of TAO, XBT and T/P data. The relative importance of the different observation systems will be assesed.

EOF- AND WAVELET ANALYSIS OF THE SEA SURFACE VARIABILITY

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A series of global gridded sea surface height models has been generated from Topex/Poseidon altimeter data, covering a period of at least four years. Height anomalies, performed relative to a four year mean sea level, are used to study the sea surface variability using the method of empirical orthogonal functions (EOF) and principle components as well as wavelet analysis.
The space-time distributed height anomalies are separated into temporal parts, represented by the principal components, and spatial parts, described by the empirical orthogonal functions. The latter are computed by a singular value decomposition of the matrix of the height anomalies.
The principal components are investigated by wavelet transform in order to determine both the dominant periodic and the significiant aperiodic oscillations of the sea surface. The wavelet method is an excellent tool for analysing signals with time dependent amplitudes and/or frequencies. Local signal variations are detected in an adaptive time-frequency window. The current analysis is based upon the Morlet wavelet, often used in geodetic applications.
The spatial and the temporal distribution of the first few modes are shown together with the results of the wavelet transform of the principal components. This illustrates how the annual variability as well as phenomena like El Nino are represented.

THE BLACK SEA VARIABILITY RESULTED FROM THE WATER BUDGET.

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Seasonal variability of river runoff, evaporation, precipitation and water flow through Bosporus and Kerch straits induces changes of the Black Sea level with amplitude up to 35cm. Simple two-layer model analysis shows that the response of the closed basin to the boundary water fluxes is barotropic mainly. Moreover, it is spatially uniform in the deep part of the Black Sea since the size of the basin is much smaller than the barotropic Rossby radius. Satellite altimetery data of TOPEX/POSEIDON and ERS-1 missions provides unique possibility to verify the theoretical results. Averaged data along each track, crossing the Black Sea are used. There is good correspondence of different time series obtained after the averaging of the open sea level data. These data are also in good agreement with river runoff, recalculated to the mean Black Sea level variability due to the continuity equation. The behavior of the sea level in the shallow coastal zone is more complicate. There is the phase shift between coastal sea level observations and satellite altimetery data for the open sea. Coastal sea level observations itself demonstrates also the phase shift between data sets obtained in different points along the Black Sea coast. Coastal trapped and shelf waves are the most feasible causes of the observed sea level structure.

THE POTENTIAL FOR USING OCEAN GENERATED ELECTROMAGNETIC FIELDS TO REMOTELY SENSE OCEAN VARIABILITY

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The flow of the electrically conducting ocean through the Earth's main magnetic field generates secondary electromagnetic fields. For some time electric field measurements have been made in the ocean to determine the ocean flow. D. Winch and K. Runcorn have speculated recently that magnetic field satellite surveys might be used to monitor the ocean generated electromagnetic fields, and that these signals might be inverted to gain information about variations in ocean circulation. We calculate global three-dimensional electromagnetic fields generated using ocean data from the German OPYC model and give an overview of the form and magnitudes of the ocean generated electromagnetic fields both in and outside of the ocean. The ocean-generated magnetic fields are typically less than 10 nanoteslas outside of the ocean (but can reach a couple hundred nT inside the ocean) and although small are above the detectability level of ground observatories and some of the previous satellite measurements. We discuss these results and describe both the potential benefits and difficulties in extracting and inverting the ocean signals from the geomagnetic records. Discussion of this topic is timely since the potential use of satellite magnetic data in ocean and climate studies could be made more feasible with coordinated efforts in future satellite missions such as CHAMP.

ASSIMILATION OF ALTIMETRIC DATA IN AN OCEAN MODEL FOR FISHERIES STUDIES IN UPWELLING AREAS

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The coastal ocean upwelling phenomenon is an important processes studied in oceanography. Many studies based directly on satellite observations were carried out to locate and follow this phenomenon on the ocean surface. Advanced data assimilation methods are essential to infer its subsurface dynamics in deep and shallow ocean from satellite data. With the tidal mixing, the coastal ocean upwelling constitutes the major process for nutrient regeneration in the surface layer. The surface Ekman layer transport produced by the phenomenon, and related currents are an important factor for larvae and small pelagic life. Studies and investigations using satellite and fisheries data and some assumptions on the current behaviour try to identify the physical forces that control the growth of small pelagic fish populations. Up to now (to our knowledge), the dynamics resulting from the assimilation of satellite observations have not been used for studies in this discipline.
A project is undergoing at the JRC SAI/ME unit to assimilate altimetric data in a primitive equation model using a four-dimensional variational assimilation scheme, in order to obtain such a description of the dynamics in upwelling areas. More details of the project and its current state of development will be presented during this session of the EGS General Assembly.

G6 High resolution monitoring of land and ice surface with altimetry and SAR interferometry

Convener: Klees, R.
Co-Convener: Remy, F.

SURFACE MEDDIES TRACKING USING SPATIAL TECHNIQUES

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The analysis of ocean water masses using traditional oceanographic techniques, including RAFOS, has allowed to track the upwelling of Mediterranean water forming mesoscale eddies, with a different thermohaline composition of its surrounding Atlantic masses, in the Iberian Atlantic west of the Portugal coast. The dynamic of the region is quite complex and is of particular interest to use data assimilation that combines classical and spatial techniques. To detect MEDDIES with satellite altimetry we have defined a rectangle between longitudes 340‖ and 353‖ and latitudes 36‖ to 43‖N, where MEDDIES where detected by lagrangian methods, according with information received from the Portuguese group IOCEANO. With preceding information we have compared, on this geographic area, the behaviour of the different altimeters, tracking along its paths the dynamic signal time series. A comparison was also made between the average behaviour of the dynamic signal over windows with a surface extension of the size of the MEDDIES (0.5‖X0.5‖) and a dynamic sea surface reference obtained averaging the time series over larger windows of 3‖X3‖. Our result shows the track of a possible MEDDIE crossing the area from 38‖N, 12‖E in 26 July 1994 to 37‖N, 13.7‖E in 26 August 1994. The possible MEDDIE was simultaneously tracked by two RAFOS and detected as a different signature surface in an ERS-1 SAR image.

Radar investigations of the deep-ocean internal solitons in the North-Western Pacific

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A detailed analysis of sea surface Ku-radar images collected in IKI RAN during regular many years experiments (1979-1991) from aircraft has showed that in the North-Western Pacific near Kamchatka there were the regions of regular manifestations of deep ocean internal waves. Some of the soliton-like trains of internal waves seemed to propagate from the open ocean to shelf. The direction of propagation of the trains was estimated using some specific features in the trains' surface manifestation. The simultaneous contact measurements of hydrological and oceanographic parameters from research vessel have confirmed the availability of internal waves in the testing area. The ray calculations have confirmed that there are some locations at the continental slope where the slope inclination is critical for the semidiurnal internal tide. The internal tides generated in these locations propagate along the wave characteristics (rays) and may evolve in the upper ocean in trains of the solitons visible in the radar images as the rips/slicks bands moving shorewards.
This work was done by financial support of RFBR Grant 96-05-65518

ACCURACY ASSESSMENT OF ALTIMETER DERIVED ORTHOMETRIC HEIGHTS USING REGIONAL DIGITAL ELEVATION MODELS.

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The ERS-1 geodetic mission resulted in the acquisition of large volumes of altimeter echoes over non-ocean surfaces, potentially enabling the generation of millions of height points over land. However, highly variable and complex echoes are returned from land topographic surfaces. An expert system has therefore been developed to retrack individual surface echoes using a range of retrackers specifically configured to interpert waveforms over land. Data from the entire geodetic mission has been processed to generate a Regional Altimeter Product (RAP) database.
In order to utilise these data, validation of the altimeter derived heights is required. A series of comparisons has therefore been carried out with accurate regional Digital Elevation Models (DEMs), to determine the bounds within which the RAP data can be expected to perform reliably. Results from a series of such comparisons are presented in this paper, including a large scale comparison with a 9" DEM of Australia. Results confirm the accuracy of altimeter derived orthometric heights for a range of terrain types, and illustrate the value of this unique dataset.

LAND SUBSIDENCE MEASUREMENTS AT CERRO PRIETO GEOTHERMAL FIELD (BAJA CALIFORNIA, MEXICO) USING SAR INTERFEROMERY.

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Repeat-pass interferometry has a high potential for the measurement of displacement field over large areas or land subsidence at fluid exploitation or mining sites. The Cerro Prieto pull-apart basin, which is part of the Salton Trough-Gulf of California system of spreading centers, is well known for its high seismic activity, either from tectonic origin or triggered by the exploitation of a geothermal field. Vertical movements have been observed along the southern end of the Imperial Fault in the Mexicali Valley and around the geothermal field. A radar monitoring of the Cerro Prieto geothermal field was carried out from 1993 to 1996. Preliminary results of ERS differential interferograms and geocoded maps are presented for this area. Differential interferograms were generated using ERS SLC data, combined with a DEM. Some results of InSAR processing are presented using our in-house developed interferometric software package. Monitoring of the area by geodesy and a crackmeter, further enable to check the interferometric results through direct comparison with field data. The study has been carried out also by taking into account the seismic activity of the area and assessing its influence on ground movements.

ERS-1&2 TANDEM MISSION INSAR DATA OF ANTARCTICA - GLACIOLOGICAL APPLICATION AND ASSESSMENT OF ACCURACY

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In 1996, during the ERS-1&2 tandem mission, several consecutive passes of ERS-1&2 capable for SAR interferometry were acquired covering the region of the Schirmacher Oasis / Dronning Maud Land. All these passes were recorded by the Japanese antarctic station Syowa. This study utilizes SLCIs (full scenes) to compute amplitude and phase coherence images as well as interferograms. The objectives of this study were to measure the ice velocities of the outlet glaciers, to determine the tidal displacement of the shelf ice and to map the grounding line. The short interferometric baselines during the time of acquisition were suitable for studying motion phenomena. Both ascending and descending tracks were used to derive velocity fields. Ground truth data were incorporated to assess the accuracy of the interferometrically measured displacements.

G6

NEAR-GLOBAL CROSSOVER ANALYSIS OF ERS-1 ALTIMETER DATA OVER LAND

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It has already been established that the number of valid returns over land from the ERS-1 altimeter during the geodetic mission far exceeds original expectations. In order to utilise fully these data over land, the precision to which heights can be generated from echoes obtained over topographically varying surfaces must first be quantified.
For this research, Waveform Altimeter Product (WAP) data have been processed to generate a Regional Altimeter Product (RAP) using an expert system which retracks the altimeter returns using a range of new land-specific retrackers.
This paper presents near-global results from analysis of all geodetic mission crossovers over land where valid RAP data exist, grouped into 15 degree squares for ease of presentation. The extremely promising results demonstrate that globally, in any 15 degree square, between 15% and 70% of the crossover height differences are less than 1m. The overall total percentage of crossovers over land where the height differences are less than 1m is 40%, representing 353771 out of a total of 889736 crossover pairs.
Also presented is an analysis of the distribution of crossover height differences with retracker type, and finally, comparisons with ground truth data are given.
These results clearly demonstrate the very good internal consistency of the RAP dataset, and show that using these land-specific retrackers accurate predictions of orthometric height can be made.

TOPOGRAPHY AND SURFACE FLOW OF THE GEIKIE ICE CAP DERIVED FROM SAR INTERFEROMETRY, LASER ALTIMETRY AND GPS MEASUREMENTS

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Four ERS-1/2 SAR interferograms, two from ascending and descending passes respectively, covering the Geikie ice cap situated at approx. 70 N, 25 W were used to determine both the topographic and the deformation component of the interferometric phases. The Digital Elevation Model (DEM) was constructed utilizing reference points obtained by laser altimetry and static GPS. A coarse model of the flow pattern of the small ice cap was derived from the deformation component of the interferograms. Velocity vectors determined by repeated static GPS positioning of 5 reference poles were used for evaluation.

Satellite radar altimetric survey of the polar ice caps and wind induced features.

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One objective of satellite radar altimetry above ice sheets is to build time series of the ground height in order to conclude whether they are growing or shrinking. Since 1991, ERS1 has been launched and releases radar altimetric measurements up to 81.5 ° latitude. The subject of the presentation is to examine the possible effects of the interaction between the radar wave and the snowpack surface on the height measurement. The principal problem treated here is the difference of measurement between ascending and descending tracks. This difference reaches 1 m in height and 1 dB in backscattering in some regions and is observed repetitively from one cycle to the other. After having a look on the difference between ascending and descending radar echoes, we conclude that there is a difference of apprehension of the surface wind induced features related to radar waves penetration inside the snowpack. We used observations of the Seasat scatterometer to estimate independently the signal that could be inferred by wind features. The result is convincing and allows us both to map the effect of wind on radar altimetric measurement and to discuss on the possible long-term altimetric variations induced by climatic changes.

SMALL-SCALE MOTION IN ALPINE REGIONS BY MEANS OF ERS SAR INTERFEROMETRY

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Methods and potential applications of differential SAR interferometry (DINSAR) for mapping and monitoring small scale motion in alpine areas are investigated within a project of the International Decade for Natural Disaster Reduction (IDNDR), sponsored by the Austrian Academy of Sciences. Based on an extensive data set of ERS-1 and ERS-2 SAR images from the Austrian Alps coherence conditions were investigated for periods from one day to one year. Whereas in forested areas interferometric correlation is low already after one day, above the treeline the coherence of selected interferometric pairs is still sufficient for DINSAR analysis over one year. Interferometric pairs from one day repeat passes with high coherence are used for subtracting the topographic phase during differential processing. Differential interferograms have been generated for different time periods, ranging from one to three days to derive glacier motion, five to ten weeks to study the motion of block glaciers, up to one year to monitor slope motion. Ice motion can only be derived during the cold season, because the C-band signal of melting snow and ice decorrelates within one day. The best season for DINSAR in ice-free Alpine terrain is summer. One of the examples with ERS SAR is a motion map for a slope above a hydropower reservoir, with a mean motion of 1.5 cm over one year. The investigations demonstrate the sensitivity of DINSAR to small-scale motion.

High-resolution Antarctica topography and surface features computed with altimeter data of the geodetic ERS-1 mission.

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The remote sensing satellite ERS-1 launched in 1991 was placed on a geodetic (168-day repeat) orbit between 1994 April and 1995 Marsh. We have analysed the waveform altimetric data from this orbit to compute map with 1/30° grid size. Data processing consists in correcting from environmental factors, editing, retracking the waveform, reducing the radial orbit error through crossover analysis, correcting from slope error up to the second order. We develop a retracking techniques that allows the restitution of three waveform parameters related with surface and subsurface snow characteristics that are mapped by the same way.

The map of the four parameters shows a lot of surprising features. The surface topography map exibits area abnormally flat such as the well-know « lakes », or steepyly sloping area due to bedrock topography. Important flow -stripes on ice shelf are also clearly visible. The maps of the parameter deduced from the waveform shape and intensity also show surprising details.

ICE SHEET RHEOLOGY FEATURES DERIVED FROM ERS-1 PRECISE TOPOGRAPHY

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The high quality and coverage of the ERS-1 radar altimeter, help provide a very accurate surface topographic map covering 80% of the Antarctica ice sheet and the whole Greenland. It contributes significantly to glaciological studies such as ice sheet flow modelling.

In one hand, the topography allows estimation of ice sheet flow direction, convergence and divergence of the ice flow, and thus the balance velocity. In the over hand, the topography allows estimation of basal shear stress that is related to deformation velocity.

The comparison of balance velocity and deformation velocity permits to fit and improve deformation velocity, but also points out very important discrepancies that cannot be explained only by a bad knowledge of the involved parameters.

G7 Joint EGS/AGU Symposium on geodetic observation and geophysical interpretation of mass movements in the Earth system (co-sponsored by SE)

Convener: Dickey, J.O.
Co-Convener: Reigber, C.

01 Solid Earth and core

Convener: Richter, B.

RESULTS OF GPS OBSERVATIONS DURING THE SERIES OF EARTHQUAKES IN STON REGION AT CROATIAN SOUTHERN ADRIATIC COAST IN SEPTEMBER 1996.

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The Croatian southern Adriatic region of Ston, near Dubrovnik, a well known as seismicly active area, was hit by a series of earthquakes in September 1996. At the same time, for most of this period, the international high precision GPS campaign CROREF'96 was undertaken in the surounding area by the IFAG, Croatian National Geodetic Authority and Faculty of Geodesy at the University in Zagreb.

The collected data are processed and the effect of the earthquakes on the position of observed points has been investigated. This paper deals with the results of this research effort.

SOME EFFECTS IN PERTURBED MOTION OF THE EARTH'S RIGID CORE

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Dynamic effects in translational motion of the rigid core (RC) into liquid core of the Earth due to gravitational attraction of the redistributed masses of the external envelope of the Earth (corresponding to the different geophysical processes) are studied. Restricted treatment of the problem about RC motion is used. RC is considered as a small spherical body with a small mass, moving in the ideal liquid medium. Reduced equations of motion are linear . Suggested method uses the special expression of the perturbing force through the radius-vector of the Earth's mass center (Barkin,1996). It let to use effectively wide set of results which were obtained by participants of the IERS Geocenter Campaign (president Dr. Jim Ray) in 1997 (Brosche and Wuensh; Montag, Gendt, Reigber, Wilson, Zhu; Dong, Dickey, Chao and Cheng; and others). As result the parameters of the possible linear trend of the RC were evaluated. Amplitudes, phases and frequencies of the RC oscillations due to gravitational attraction by oceanic tides were found. Annual and semiannual RC oscillations due to gravitational influence of the seasonal redistributed masses of the atmosphere, oceanic tides, ground water and oth. have been described. Bias of the RC due to these factors can reach a few decimeters. Amplitudes of the RC perturbations due to direct attraction of the Moon and Sun are evaluated.

REPEATED GRAVITY MEASUREMENTS IN THE AZORES 1992-1997

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Within the framework of the project TANGO, we have made absolute measurements at three stations: Faial in 1992, 1994, and 1997; Flores in 1992 and 1997; and S. Miguel in 1994 and 1997. The work at S. Miguel was performed in cooperation with the Furnas – European Laboratory Volcano programme. Preliminary results of 1997 show a significant increase in gravity both at Flores (+20 ± 7 μgal over 1992) and at Faial (+15 ± 7 μgal over the mean of 1992 and 1994) while the change at S. Miguel is not significant (+7 ± 7 μgal over 1994). The JILAg-5 of the Finnish Geodetic Institute was used. Reference measurements in Finland before and after each campaign, and at two high-quality sites in Spain after the campaign seem to exclude the possibility of a shift in the instrument. The standard errors (1 σ) are based on a conservative estimate of 5 μgal repeatability for a station occupation. The results are not corrected for variation in environmental factors like subsurface water storage, which may be appreciable as the measurements were done in different seasons. In addition, we discuss three relative campaigns executed in parallel with the absolute measurements.

THE GRAVITY RECOVERY AND CLIMATE EXPERIMENT (GRACE)

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For a number of applications in oceanography, hydrology, glaciology and the solid Earth sciences, the static and time-varying global gravity field can provide a critical observational constraint. The Gravity Recovery and Climate Experiment (GRACE) is intended to provide measurements of the Earth's gravity field variations with unprecedented accuracy. GRACE was recently selected under the NASA Earth System Science Pathfinder (ESSP) program. The proposed GRACE mission consists of two satellites, co-orbiting in a polar orbit and separated by 200 km. The orbit altitude will decay from an initial value of 450 km to 300 km during the five year mission lifetime. Each satellite will carry a micro-wave, dual frequency one-way ranging system, which will provide measurements of the differential satellite perturbations due to variations in the static and time varying components of the Earth gravity field. Each satellites will also carry a high precision accelerometer and GPS receivers to aid in the recovery of the gravity field from the observational data. The extended mission life coupled with the precision of the measurements will provide a static gravity field model which is several orders of magnitude more accurate than current models and will provide measurements of the temporal variations which will yield new insight into mass and momentum transport among the Earth's atmosphere, ocean and land components. These results will also satisfy the requirements of a number of national and international scientific programs directed at studying global change. In this paper, we provide a summary status of the project to date. Also, we will review the science rationale and capabilities of GRACE for the measurement and monitoring of the Earth gravity field changes. The impact of the results from GRACE on our measurement and understanding of global climate change, and its interaction with other space and ground-based geophysical data sets will be discussed.

CHAMP - THE NEXT MISSION FOR MAJOR IMPROVEMENT IN RECOVERING THE GEOPOTENTIALS

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In mid 1999 the German small satellite CHAMP will be launched aiming at a drastically improved recovery of both the gravity and magnetic field and the time variability in both fields. For doing this, the spacecraft will be equipped with a very precise magnetometry instrument package, advanced GPS onboard receiver, a highly precise three-axes electrostatic accelerometer and some additional support equipment (laser reflector, star imager, ion drift meter, Langmuir probe). The CHAMP onboard equipment will be used in addition to obtain information on the vertical structure of the Earth's neutral atmosphere and ionosphere by limb sounding. The satellite is planned to collect data over a 5-years mission period and from a near-polar orbit at altitudes between 450 and 250 km. Mission data will significantly contribute to the development of a credible model of the Earth's interior, to shed more light on the pattern of fluid motions at the core/mantle boundary, to improve our knowledge of the magnetisation of the Earth crust and to study short- to medium-term variations in the gravity and magnetic field and their relation to geophysical processes. CHAMP's measurements will help to better predict changes and assess the consequences.
In the presentation, the mission preparation will be shortly reviewed, possible scientific and practical applications of the mission will be outlined and the coordination of the science programme be explained.

THE INFLUENCE OF ATMOSPHERIC MASS REDISTRIBUTIONS ON GRAVITY

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Surface gravity observations are influenced by atmospheric effects over a very broad frequency band ranging from years to minutes. The effects are due to a loading process combining Newtonian attraction and elastic deformation of the ground. It is very classical in gravimetry to perform atmospheric corrections on gravity data with the help of a transfer function called barometric admittance (typically -0.3 microgal/millibar) between gravity and pressure both measured only locally; however several studies have shown that this factor is variable in time as well as in frequency. For periods larger than 10 days, cross-correlation analyses between local gravity and pressure point out that a more global approach based on atmospheric loading Green's functions is required. We will use a global pressure data set (1.125° x 1.125°, 6 hour sampling) provided by ECMWF (European Centre for Medium Range Weather Forecasts) to model the gravity changes at different stations where superconducting gravimeter records are available. The differences between global and local approaches will be emphasized especially for the 3000 day long record in Strasbourg. A further modelling taking into account the stratification in the atmosphere will be tested with respect to the thin layer approximation (surface loading). Finally our global atmospheric loading model will be used to investigate the gravity signature caused by planetary organised waves like the annual and diurnal atmospheric tides S_a and S_1 of thermal origin.

ON THE POSSIBLE INTERFERENCE OF DATUM EFFECTS OF GEODETIC MODELS WITH TEMPORAL CHANGES OF GEOPHYSICAL PARAMETERS

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In combining the principle four components, frame, earth rotation, kinematics and gravity, geodesy is on its way to establish a global integrated geodetic and geodynamic observing system. The observing system, in order to meet its objectives, has to combine greatest measurement precision (10**-8 to 10**-9, relatively) with spatial and temporal consistency and stability over decades. Aspects such as the definition of a terrrestrial reference frame, its time evolution, its consistency with gravity modelling but also the establishment of a unified global height system will have to receive greatest attention. In particular it is to be avoided that changes in datum parameters interfer with geophysical parameters such as the motion of the center of mass, crustal motion or polar wander.

ERROR SOURCES FOR GRAVITY FIELD MISSIONS IN SPACE AND THEIR EFFECT ON THE FINAL RESULTS

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During the last years several satellite missions for the determination of the Earth's gravity field with high accuracy have been investigated (e.g. GRACE, GOCE). These missions are based upon two different measurement concepts: gradiometry, i.e. the measurement of differential accelerations over a short baseline inside a spacecraft, and satellite-to-satellite tracking, the measurement of ranges or range rates between two satellites following each other.
Both concepts have their advantages and disadvantages with respect to the modelling of the Earth's gravity field. They show either a better spatial resolution or a higher accuracy depending on the considered spectral domain; also the temporal resolution differs.
We present a discussion of the main error sources (e.g. center of gravity variations, measurement of angular velocities or perturbations by the thrusters) which may limit the accuracy of each mission. Finally we give an outlook how these driving errors affect the end-products (e.g. geoid), especially how the results changes if some requirements cannot be kept.

SUBDUCTION AND CONTINENTAL COLLISION IN THE MEDITERRANEAN REGION

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The Mediterranean region is considered a natural laboratory for studying the occurrence of extensional tectonics due to back-arc extension in subduction environments, within a context of continental convergence. Numerical modelling of the major tectonic mechanisms allows us to provide a quantitative and physical understanding of the dynamic evolution of the Mediterranean region and to make predictions on future trends in crustal deformation rates which can be compared with ongoing GPS campaigns and sea-level changes along the coastlines. Predictions from the physical modelling can also be used to recognize those areas subject to the largest deformation rates, which can be relevant for the planning of future GPS campaigns. Results from 2-D and 3-D numerical modelling is provided for a variety of tectonic environments in the Mediterranean region, for the past and present day tectonic settings, in order to shed light on recent developments in the field of the physical modelling of plate tectonic processes at the Mediterranean scale.

G7 Joint EGS/AGU symposium on geodetic observation and geophysical interpretation of mass movements in the Earth system (co-sponsored by SE)

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02 Ocean and hydrosphere

Convener: Chao, B.F.

IMPACT OF MANTLE CONVECTION ON EARTH ORBIT PARAMETERS AND PALEOCLIMATE

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We present here the results of a recent study of the influence of mantle convection on the Earth's orbital parameters, namely obliquity and precession rate, and the consequent effect on paleoclimate [**Forte and Mitrovica**, *Nature*, 1997]. The convective flow is calculated on the basis of models of the three-dimensional density structure of the mantle that are constrained to satisfy a large and diverse set of global seismic and geodynamic data. An essential aspect of this ongoing multidisciplinary study is the simultaneous consideration of all the constraints posed by global seismic data (travel times and waveforms), convection-related surface observables (plate motions and gravity anomalies), glacial isostatic adjustment data, geodetic inferences of core-mantle boundary flattening, and mineral physics data. Using viscous flow theory we determine changes in the Earth's dynamic ellipticity over the past 20 Ma and then apply these perturbations to the many-body orbital solution of **Laskar et al.** [1993]. We thus find that convection-induced changes in the Earth's flattening significantly affect time variations in the obliquity, precession rate, and hence high-latitude summer insolation. This result has significant implications for the interpretation of climatic cycles recorded in sedimentary sequences and other climatic proxy records.

TEMPORAL VARIATIONS OF CONTINENTAL LAKES LEVEL FROM TOPEX/POSEIDON (1993-1996)

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The water level of continental lakes fluctuates due to variations in evaporation and precipitations within their catchment basins in response to regional climatic changes. With satellite altimetry, lake level variations can now be monitored almost continuously with a precision of few cm. Here we present water level changes of three American Great Lakes (Superior, Michigan and Huron) and three African lakes (Tanganyika, Malawi and Turkana) based on 4 years (1993-1996) altimetry data of the Topex/Poseidon (T/P) satellite. The level of these lakes shows a dominant annual cycle highly correlated with precipitations. American Great Lakes are regulated hence present little interannual variations. This is unlike African lakes which markedly respond to regional (possibly global) climatic changes. A large water level decrease of lakes Tanganyika and Malawi (≥ 20 cm/yr) is observed by T/P for 1993-1996. This trend is associated with recurrent droughts recorded in East and South Africa since the early 1990s, as a result of the series of recent ENSO events.

The Role of Ocean Variability in the Earth's Gravity Field as Predicted From the Parallel Ocean Climate Model

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This research examines the role of the oceans in the temporal variability in the Earth's gravity field as predicted by the Parallel Ocean Climate Model. This free-surface high resolution ocean model allows the estimation of variability in the Stokes coefficients resulting from mass redistribution forced by wind fields and heat fluxes predicted from an operation meteorological center. First, we examine features of the Earth's temporally varying gravity field that are observable with modern space geodetic techniques by computing time variations in the Stokes coefficients using the model's mass fields. Next, we estimate the zonal harmonics as well as the "effective" J_2 and "effective" J_3 time series using sensitivities from the LAGEOS satellites. Finally, comparisons to the observed temporal variability in the gravity field show that oceanic mass redistribution appears to explain some of the variations unaccounted for by atmospheric mass redistribution and continental water storage.

TOPEX/POSEIDON OBSERVATION AND GLOBAL WATER MASS BALANCE

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Analysis of TOPEX/Poseidon satellite altimeter data indicates that the global mean sea level variation has a clear seasonal signal with an amplitude of about 2 to 3 mm, along with a long term drift. It is generally believed that this seasonal variation is associated with mass redistribution within the global hydrological cycle plus steric thermal contributions. Using the NCEP-NCAR Climate Data Assimilation System I (CDAS-1), we investigate seasonal variations of the integrated water vapor in the atmosphere and water storage changes in the soil moisture, snow, and ice. Total water mass fluctuations in the atmosphere, soil moisture, and snow depth fields are converted into equivalent mean sea level variations by conserving the surface and atmosphere water mass. Predicted seasonal global mean sea level variations agree well with observed seasonal variability in both amplitude and phase, after a steric thermal correction is applied to the TOPEX/Poseidon data using a simplified thermal model derived from the NOAA World Ocean Atlas 1994. This result indicates that the TOPEX/Poseidon satellite altimeter may provide key information for the global water mass budget by placing observational constraints on the mass budget variations predicted by global atmospheric and hydrological models.

ESTIMATES OF LARGE SCALE CHANGES OF MASS IN THE OCEANS FROM SATELLITES.

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Satellite observations of the sea level and the sea surface temperature have been used in a global analysis of the variations in those quantities over about four years. Some similarities between the changes in the sea level and the sea surface temperature exist which indicate that parts of the changes in sea level are caused by thermal expansion of the ocean water column. Especially, at mid latitudes the annual cycles of the two quantities are highly correlated. A quantitative analysis of the results may provide information about the relation between sea level and sea surface temperature changes. In this study the large scale variations of the sea level and the sea surface temperature are described. Then the thermal expansion is extracted, so that the changes in mass are obtained.

IMPACT OF GRACE GRAVITY MISSION ON OCEAN STUDIES

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For computing surface geostrophic currents, errors in the GRACE geoid will exceed altimeter errors on scales less than 300 km. Prior to GRACE, this length scale is 2000-3000 km. GRACE will thus substantially improve estimates of global surface circulation and its impact on heat flux. We find that the uncertainty in surface mixed layer heat advection will be ¡10 Wm2 in the North Pacific. Time-varying gravity measurements are expected to resolve mass variations in the ocean of the equivalent of 1-3 mm water thickness on circle radii ¿ 300 km and seasonal and longer time scales. As an indicator of the variation of the vertically integrated mass of a water column, or the equivalent bottom pressure, these gravity measurements will provide a coarse view of the basin-scale abyssal pressure field variations and the associated deep geostrophic circulation as has never been possible before. Secondly, when combined with satellite altimeter data, the difference will allow the separation of the steric component of sea level variability, since the gravity signal represents the non-steric (barotropic) portion. The steric term thus derived can serve as an indicator of ocean heat storage variability. We will present simulations using output from state-of-the-art ocean general circulation models (OGCMs) of the seasonal and interannual ocean gravity and steric signals that may be observed in this manner with GRACE data.

ATMOSPHERIC AND OCEAN LOADING IN GPS AND VLBI.

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The physical process as well as the computational procedures of ocean loading tides and atmospheric loading will be reviewed in this presentation. The impact of loading effects is shown in the cases of several techniques. Special attention is payed on observing the fully 3-D short-period motion as observable by GPS and VLBI. In particular the observed lunar tidal species show good agreement with the model while solar species are perturbed by anomalies at the sidereal period and its upper harmonics, probably relating to orbit errors.
We point out implications of load-induced motion with respect to motion of the origin of the reference frame and carefully distinguish this motion from deformations at spherical harmonic degree one. We show a comparison from a number of ocean tide models including recent results from Topex/Poseidon.
The situation of atmospheric loading appears less clear. Focussing on Northern Europe, previous work arrived at a very low impact of loading predictions on residual error and low figures of signal admittance in VLBI and GPS. Analysis of GPS in the BIFROST project as well as VLBI experiments tend to confirm this finding. As the number of observations grow, admittance homes in on values between 0.2 and 0.5 (predicted versus observed loading effect). The span is outside the limits within which the inverted/noninverted or even a dynamic barometer ocean response operate. Thus we tend to conclude absorption of the effect into other parameters, primarily the troposheric wave propagaton delay.

G7

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Co-Convener: Reigber, C.

03 Cryosphere

Convener: Dietrich, R.

Sponsorship: AGU

Review of SAR applications in Antarctic glaciological research.

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Polar ice sheets play an important role in the dynamic earth system. Their mass varies over time scales of hundreds to thousands of years, interacting with the atmosphere, ocean and lithosphere. SAR interferometry has proved to be a very successful technique for determining continuous surface velocity fields. However, to determine the satellite baseline accurately requires ground control of comparable accuracy. In areas where there is no fixed markers, the best achievable accuracy has been obtained from using ground surveys and GPS positioning for tie points. A full three-dimensional solution is not possible with only one, or at most two, different look directions and additional assumptions have to be made. Vertical movement caused by tides can be identified around the grounding line and is the clearest way of determining its position. Differential interferometry, with two or more coherent pairs of SAR images, allows a uniform velocity field to be subtracted to leave the topographic signature. Experience shows that coherence cannot be guaranteed even for favourable baselines (usually less than a few hundred metres) because of rearrangement of the surface by snow fall or wind induced drift. SAR amplitude images are excellent for discriminating areas with high backscatter values, caused often by crevassing. Ice stream margins are easily distinguished and well defined. In the warmer coastal regions, the surface backscatter shows a strong seasonal variation which can be used to measure the length of the summer melt period, a parameter of some climatological interest.

ICE FLOW VELOCITY PATTERN OVER DJANKUAT GLACIER IN THE CAUCASUS

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The field of superficial ice flow velocities of compound Djankuat Glacier, Central Caucasus, consisting of several ice streams, was investigated by means of geodetic methods. Horizontal and vertical components of ice flow vector were determined by intersection. For the first time they were estimated over the entire area of Djankuat Glacier. Absolute values of horizontal component average to 5-10 cm/day on the snout and 10-20 cm/day in the accumulation area. As for vertical component, it was calculated as a difference between surface hypsometry changes and specific ablation rate; hereby, their vectors are directed mainly downwards in the firn basin and upwards on the snout. Detailed glacier movement monitoring throughout 3 last observation years reveals also peculiarities of its intra-seasonal dynamics during melting season for the whole glacier surface and of its inter-seasonal dynamics for the ablation area. Identification of the uneven ice divide within the divergent flat firn plateau at the crest zone by means of geodetic measurements and pseudo-parallax stereophotogrammetrical method discloses its migrating pattern during not only 13 last years of instrumental control but over many decades by indirect witness. Traces of kinematic wave engendered by the recent ice mass redistribution within the plateau can be detected from the subsequent alteration of Djankuat Glacier hypsometry. Possible reasons of ice divide migration are concerned too.

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04 Atmosphere

Convener: Geiger, A.

CLIMATE CYCLES IN GRAVITY FIELD VARIATIONS.

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Global change is generally accompanied by mass redistributions. These are caused by mass exchanges between the hydrosphere and cryosphere, changes within the hydrological cycle, and within the atmospheric circulation.The influence of atmospheric circulation on variations of the gravity field was studied using air pressure variations from 1900 to 1988. The calculation of the amplitude spectra of different Stokes coefficients showed that the amplitudes of climate cycles are in the same order of magnitude as those of seasonal variations. The most evident signals of climate cycles are contained in the variation of the gravity centre.

TEMPORAL VARIATIONS OF THE GEOPOTENTIAL: ATMOSPHERIC EXCITATION

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The Earth is a complex system with dynamical subsystems (such as the overlying fluid hydrosphere and atmosphere, underlying metallic core, and mantle) with complicated interactions among them (such as the melting of glaciers, sea level rise, and post-glacial rebound). Changes in the inertia tensor of the solid Earth are brought about by interfacial stresses, the gravitational attractions associated with astronomical objects and mass redistributions in the Earth's fluid and solid region. As the Earth's gravitational field changes only in response to net mass redistribution, observations and analysis of the Earth's time varying global gravitational field permits the isolation and study of the changing mass distributions and serves as a geophysical indicator. Intraseasonal through interannual variations in the Earth's gravitational field are investigated through the analysis of LAGEOS I satellite laser ranging measurements and are compared with those produced by atmospheric mass redistribution as inferred from global surface pressure data from the National Center for Environmental Prediction (NCEP). The technique of Singular Spectrum Analysis (SSA) is applied; implications of results will be discussed.

VARIATIONS IN THE DISTRIBUTION OF ATMOSPHERIC MASS

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Changes in the distribution of atmospheric mass over the earth on time scales ranging from seasonal to semidiurnal are described. The role of water vapor is outlined. Model and observed data are used to estimate resulting semidiurnal variations in mountain torques.

MASS MOVEMENTS INSIDE THE SOLID EARTH INDUCED BY ATMOSPHERE, OCEANS AND SOLID EARTH INTERACTIONS

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Global atmospheric loading induces various interactions between atmosphere and oceans, between atmosphere and solid earth and between solid earth and oceans. We consider the static response of non-global oceans overlying an elastic Earth which is induced by the atmospheric loading located over the continents. Our model take into account the significant oceanic response associated with the continental atmospheric loading, relative to ocean - solid earth interaction. Temporal variations of the gravity field and geodetic sites positions driven by global atmospheric loading and non-global oceanic loading are derived using a global atmospheric pressure data set provided by the European Center for Medium range Weather Forecasts.

INFORMATION ABOUT THE ATMOSPHERE DERIVED FROM GPS OBSERVATIONS

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GPS data contains a lot of information about the atmosphere, either directly in the observations or in the geophysical parameters estimated from GPS data. The atmosphere, as a refractive medium, directly delays the microwave satellite signals. In order to model the tropospheric refraction appropriately, zenith delays and, recently, also troposphere gradients are estimated from the observations for each site. Times series of such estimates may be studied to obtain information about the atmosphere and the climate (e.g. the integrated precipitable water vapor (IPWV)) on short and long time scales.
The indirect effect of the atmospheric pressure on the continental plates (called atmospheric loading) causes variations of a few millimeters in the height components of the individual tracking sites and is difficult to detect. Clearly visible is, however, the *integrated* effect of atmospheric pressure and winds on the Earth rotation parameters. The correlation between length of day and atmospheric angular momentum (AAM) is especially pronounced.
The Center for Orbit Determination in Europe (CODE) is producing daily solutions since June 26, 1992. using the GPS data of the global IGS network. The resulting time series are analysed to see the variations in the atmosphere and their impact on polar motion and length of day.

GEOPHYSICAL SIGNALS REVEALED FROM GPS POSITION MEASUREMENTS

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GPS observations of about 40 stations distributed world-wide are used to estimate geodetic parameters as, e.g., the daily geocenter position and station coordinates. For our investigation, data of the time span June 1995 to December 1996 were analyzed. The time series of station positions was used for spectral analyses. Results show that major periods are seasonal. Besides, fortnightly periods and a few other periods were perceptible. Atmospheric pressure loading effects were compared with estimated vertical positions. It was found that pressure loading signals are clearly visible in vertical station positions. On the other hand, the vertical as well as horizontal position variations reveal several very interesting characteristics, which need new geophysical explanations.

G7 Joint EGS/AGU symposium on geodetic observation and geophysical interpretation of mass movements in the Earth system (co-sponsored by SE)

Convener: Dickey, J.O.
Co-Convener: Reigber, C.

05 Interactions between the components of the Earth system

Convener: Zerbini, S.

Sponsorship: AGU

OBSERVING SURFACE DISPLACEMENTS THROUGH INTEGRATED SPACE TECHNIQUES

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We discuss the integration of Global Positioning System (GPS) and Integrated Synthetic Aperture Radar (INSAR) technologies for monitoring surface displacements. Continuous GPS provides highly accurate and temporally dense observations, while INSAR provide somewhat less accurate but spatially dense observations. We review our approach to analyzing these data which takes into account the strengths of one technique to reduce the major errors and deficiencies in the other technique. We demonstrate our approach by evaluating coseismic and postseismic surface displacements induced by the 1992 (Mw=7.3) Landers and the 1994 (Mw=6.7) Northridge earthquakes in southern California. and subsidence in the Los Angeles basin. Furthermore, we test the feasibility of using the integrated GPS/INSAR technique to monitor interseismic strain in the Los Angeles basin.

GRAVITATIONAL INTERACTION BETWEEN THE EARTH'S ENVELOPS, THE MOON, THE SUN AND GEODYNAMIC CONSEQUENCES

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Dynamic parameters (coordinates of the mass centers, axial and centrifugal moments of inertia and others) of corresponding models of the nonsymmetric Earth's envelops: crust, lithosphere (and separate plates), mantle, supper mantle, liquid core and also of the envelopes of heterogeneities: topography, water and ice envelopes, heterogeneities on the boundaries of the envelopes (Mocho, core-mantle and oth.) (Barkin, 1995) were obtained. The basis of this construction is the Dziewonski, Morelli model of the Earth's concentric envelopes (1981) and different models of the surfaces of the boundaries of the envelopes and data about their densities redistribution (Balmino, Lambeck, Kaula, 1973; Morelli, Dziewonski, 1987; Chujkova, Maksimova, 1996) and oth. Principal vectors and principal moments of the gravitational forces of the mutual interactions of the envelopes, of the forces acting on the every local envelopes (and each plate) from the Moon and the Sun, principal vectors of inertia forces and their principal moments due to Earth's rotation have been defined and their components have been calculated. Important correlations of the directions of above mentioned force characterics with lithosphere rotation, with paleomigration of the Earth's pole, with orientation of the axes of lithospheric (geodynamic) reference system (Barkin, 1995), with magnetic center position have been established. Individual envelope's contributions in observed dynamic effects of the Earth's rotation (in chandler's pole motion in precession and nutation and oth.) are evaluated.

GEOCENTER VARIATIONS DERIVED FROM 4 YEARS OF DATA OF THE DORIS SPACE SYSTEM. COMPARISON WITH SURFACE LOADING DATA.

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Time series of the three geocenter components have been estimated at monthly interval over four complete years (1993-1996) from Doris data on Spot-2, Spot-3 and Topex-Poseidon. Doris allows 3-D absolute positioning by solving simultaneously the satellite orbit, 3-D station coordinates and velocities and Earth rotation parameters. Differences between successive monthly coordinate solutions for the whole Doris network (50 stations) and a reference multi-year solution have been minimized by adjusting classical translation, rotation and scale factor parameters. Time variations of the translation parameters are interpreted as the geocenter motion for 1993-1996 relatively to the Earth center of mass. For each coordinate the dominant signal is annual. Amplitudes are 3.4 mm, 4 mm and 4 mm on X, Y and Z geocenter coordinates respectively. Maxima on Y and Z occur in autumn and late spring in X. We compared the Doris-derived geocenter motion with the annual surface mass redistribution within the atmosphere, ocean and continent sustem. The atmospheric effect has been estimated from ECMWF pressure field. Ocean effects (circulation and sea level) have been deduced from Topex-Poseidon and the hydrological contribution has been estimated from global GEWEX data. Although each data set has some uncertainty, in particular the hydrological one, the comparison between observed and estimated annual geocenter motion is quite good.

SEASONAL WATER MASS REDISTRIBUTION BETWEEN OCEANS, ATMOSPHERE AND CONTINENTS

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Satellite altimetry from Topex-Poseidon and ERS-1 allows now to accurately estimate seasonal changes in the global mean sea level. Since we consider global averages, the observed changes can be accounted for by steric effects plus exchange of water within the ocean, atmosphere, continent system. From the several years of altimetry time-series available for both Topex-Poseidon and ERS-1, we have determined the global mean sea level annual cycle. Its amplitude is 5 mm with maxima early October. Using the Levitus et al. (1994) climatology giving temperature and salinity fields at different ocean depths, we have computed the steric component due to annual thermal expansion of the oceans and removed it from the altimetry-derived observed sea level. The residual sea level cycle can be accounted for by water mass exchange with the atmosphere and continents. Besides atmospheric precipitable water, we considered the continental water cycle. The latter includes precipitations (rain and snow), evapotranspiration and river runoff. The continental water contribution has been estimated from different hydrological data sets. The comparison between altimetry-derived sea level variation (steric effects removed) and predicted sea level (from atmospheric water vapor and continental hydrology) is very compelling, considering the rather large uncertainty affecting the continental water budget.

INTERACTIONS BETWEEN OCEANS, ICE AND SOLID EARTH: GLACIAL REBOUND IN NORTHWESTERN EUROPE AND THE EVOLUTION OF THE BALTIC SEA

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The nature of the interactions between the Late Pleistocene ice sheets, the oceans and the solid earth are well understood and the observational evidence is such that reliable parameters can be estimated that quantify the main features of these models; namely a set of effective rheological parameters describing the Earth's response and the volumes of ice involved. The degree of refinement in these models has also now reached the stage where it becomes possible to model in detail the evolution of sea and lake levels in coastal regions and this will be illustrated for the case of the Baltic Sea which, since the last major ice sheets over the region, evolved from a series of ice lakes (culminating in the Baltic Ice Lake) to an alternating sequence of marine (Yoldia and Litorina stages) and non-marine (Ancylus stage) environments. Comparisons of model predictions and observations will be made to establish the time scale for this evolution. Results will also be given for intervals going back to the Eemian.

EROSION, MOUNTAIN BUILDING AND OCEAN VOLUME CHANGE. HOW DO THESE INTERACT?

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New calculations are done to derive erosion rates for river basins. These rates depend mainly on precipitation or runoff, slopes, & temperatures. The results can be used to derive average erosion rates for continents. Because of the great size of continents, the main variable which controls erosion is the average continental elevation. These erosion rates are balanced by mountain building, which in turn is controlled by the heat generated within Earth, thus decreasing with time. It is therefore possible to calculate the time varying average freeboard. Proposals have been made that Earth is being bombarded by small cometary objects, which could be adding significant amounts of water to Earth. This addition of water can be factored in, to determine how continental area, continental thickness, & oceanic depth vary with age. These quantities are so poorly known that it is impossible to use geological evidence to limit the rate of water addition.

EARTHCENTER MOTION FROM LAGEOS 1+2 LASER RANGING: COMPARISONS WITH GEOPHYSICAL FLUIDS SERIES.

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The analysis of precise laser ranging data to LAGEOS 1 and 2 has been the mainstay in defining the geocenter for the Terrestrial Reference Frame (TRF) solutions of the International Earth Rotation Service (IERS) in the past. Recent studies have indicated motions between the space-technique-defined coordinate origin and the geocenter, due mainly to tidal and atmospheric/hydrologic processes. Our analysis covers the four year period from 1993 to the end of 1996. The data were obtained from NASA Goddard's CDDIS archive and analyzed using Goddard's GEODYN/SOLVE II software. The geocenter results are based on batches of fifteen days of data, during which period the orbit initial conditions are adjusted and Earth orientation parameters are determined daily. The site positions are fixed to a "global" solution based on the entire four year period. Force and measurement models follow the IERS Conventions, except for Earth gravity: instead of the JGM-3 model we have used the more recent EGM-96 model and the associated ocean tides model. The scatter of the three geocenter components is at the 3 mm level for x and y, and 11 mm for z. The series are spectrally analyzed and compared to series derived from observations and models of atmospheric, oceanic and hydrologic processes. Comparisons with geocenter series from alternate space techniques are also shown and discussed. The highest resolution that can be supported at present by laser ranging is also discussed.

ANTARCTIC CRUSTAL RESPONSE PREDICTIONS FROM THE CLIMAP RECONSTRUCTION AND ITS POSSIBLE SUCCESSORS

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The CLIMAP study of Denton and others, presented in the early 1980's, features a continental-scale ice dome over East Antarctica and a much smaller dome in the Antarctic Peninsula at Last Glacial Maximum (LGM). Since that study a variety of new observations relating to the extent and thickness of the Antarctic ice sheet at LGM, as well as the timing of its subsequent partial collapse, have become available. Consequently, an update to the CLIMAP reconstruction presented by Denton, Prentice, and Burckle [1991] (D91 model) features important changes, including a smaller East Antarctic dome and three domes in West Antarctica. Viscoelastic crustal response predictions (vertical and horizontal crustal motion and secular solid-surface gravity change) are substantial for both models, reaching values in excess of 5 mm/yr (uplift) over large regions of West Antarctica, for a wide range of plausible choices of mantle viscosity and timing of deglaciation. These large rates are in general agreement with the substantial uplift rates inferred in some recent three-dimensional ice sheet modelling. In detail, the spatial patterns of crustal response diverge by a factor of two or more at some inland sites in West Antarctica. Combining deglaciation scenarios with scenarios of present day mass change previously developed for secular gravitational harmonic (J_l) studies reveals inland sites where an appropriate multi-year monitoring program could help discriminate between competing scenarios of past and present day Antarctic ice mass balance.

EXOGENIC DEFORMATIONS OF THE EARTH DUE TO ATMOSPHERE AND OCEAN LOADING

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Deformations of the Earth's surfaces are increasingly observed with space-geodetic techniques. Mass movements in the atmosphere and ocean load the Earth surface and consequently deform the viscoelastic Earth and induce a gravity signal. For many studies of Earth dynamics, these deformations and gravity changes constitute a disturbing noise. However, observed deformations also carry valuable information on the viscoelastic properties of the Earth at frequencies outside the seismic band. To model exogenic deformations, both an Earth model and the loading function are required. The Earth model usually used for computations is spherically symmetric, non-rotating, elastic and isotropic (SNREI). While most of these simplifications can easily be justified, the spherical symmetry constitutes a serious deficit of the Earth model as it is not accounting for the large lateral heterogeneities in the Earth's crust. For the combined atmosphere-ocean loading, the interaction between atmosphere and ocean has to be taken into account. Particularly the frequency-dependent response of the ocean to air-pressure changes is globally still not sufficiently known from observations. Both, coastal tide gauges and satellite altimetry data suggest considerable deviations from the most often applied no-response and inverted-barometer models. Moreover, in many geographical regions, the available air pressure data may be insufficient.

ON THE RELATIONSHIPS BETWEEN SEA ICE EXTENT AND ATMOSPHERIC CIRCULATION IN THE NORTHERN HEMISPHERE

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Based on observed Arctic and Antarctic sea ice extent data during 1973-1990, the relationships between sea ice extent and atmospheric circulation in the northern hemisphere are discussed, emphasizing on the influences of variability of sea ice extent on large-scale characteristics of atmospheric circulation. The characteristics of atmospheric circulation are described by a series of indices such as the intensity of west Pacific subtropical high, the longitude of polar vortex and so on. Cross correlation analysis is used in this study. Results show that the variations of sea ice extent in both Polar Regions have responses in large-scale behaviours of atmospheric circulation. In addition, subtropical highs are most significantly affected by the variations of polar sea ice extent and take an important role in the relationships between polar sea ice extent and atmospheric circulation.

GEODESY AND HYDROLOGY

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Measurements of changes in continental water storage at scales of a few hundred km and larger are useful for global climate modeling, for better understanding large-scale hydrological processes, and for monitoring the distribution of land-based water for agricultural and water resource applications and flood hazard assessment. Traditional hydrological measurements provide information at scales of individual catchments - on the order of 10's of km and shorter, but are not well suited for providing large-scale estimates.
Large-scale water storage is accessible, in principle, using various types of geodetic measurements. Changes in the regional mass of water, snow, and ice, can produce gravitational signals large enough to be detected using either ground-based or space-based gravity measurements. Furthermore, these changes in mass load the earth and the resulting deformation can be large enough to be detected using crustal motion observations from, for example, GPS.
These hydrological applications of geodetic measurements have as yet received little attention. That will likely change as the geodetic techniques continue to mature and their non-secular systematic error sources become better understood. Particularly promising is the expected 2001 launch of GRACE: a dedicated-gravity satellite mission capable of detecting changes in continental water averaged over a few hundred km on a side, to accuracies approaching a few mm every 2-3 weeks.

G8 Integrated studies of sea-level fluctuations and crustal movements in the Mediterranean and adjacent regions

Convener: Cazenave, A.
Co-Convener: Plag, H.-P.

LONG TERM COMPONENTS OF SEA LEVEL FLUCTUATIONS IN EUROPEAN SEAS

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Sea level fluctuations relative to a fixed point of the crust, as obtained from tide gauge observations, are important for coastal monitoring. These fluctuations are the combined effect of sea level changes relative to a given reference surface and of crustal movements. The first component, which is due to global mass/volume change and to regional changes in the oceanic and atmospheric circulations, is obtained from altimetric observations, the second by computation of the geocentric coordinates of the stations using positioning techniques. We are interested in the long term sea level fluctuations. We analyse the long term variations of the absolute sea level, measured by the ERS-1, ERS-2 and Topex/Poseidon satellites, and of the relative sea level, given by the tide gauge observations, and we compare and combine locally both types of data. We analyse the correlation of the sea surface heights variations with the variations of other sea-surface and atmosphere parameters: sea surface temperature, wind speed and sea wave heights obtained by satellite observations, air temperature and air pressure at tide gauge stations locations. The analysis shows that combined satellite and tide gauge observations are contributing to an accurate analysis of sea level variations. A high coherency between some parameters of the sea-atmosphere system is demonstrated. Periodical signals are found and observations over longer intervals are necessary to give confidence to the values estimated for the trends.

PRESENT-DAY SEA LEVEL CHANGES IN THE MEDITERRANEAN AND BLACK SEAS FROM SATELLITE ALTIMETRY

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The rate of present-day global sea level rise is a central question in the current climate change debate but no reliable estimate is yet available. Although satellite altimetry records are still quite short, global as well as regional-scale monitoring of sea level changes has shown to be feasible with the most recent altimetry missions. Here we present results of present-day sea level changes in the Mediterranean and Black seas based on several years (April 1992-July 1997) of altimetry data of Topex-Poseidon and ERS-1. We discuss both the annual cycle and interannual signal. The annual cycle of the Mediterranean sea is largely due to thermal expansion of the sea water. A small non steric component is observed and discussed. At interannual time scale, the Mediterranean sea level is rising at a mean rate of ~ 9.+2. mm/yr. However, close inspection shows that between spring 1992 and winter 1995 the rate of rise was quite small. From the end of 1995, an accelerated rise is reported. It is worth mentioning that a similar behaviour is observed for the global (ocean-wide) mean sea level. A huge rate of rise is observed for the Black sea between January 1993 and July 1997. A value of 25 $\pm$ 3 mm/yr is reported from Topex-Poseidon.

SEA-LEVEL MONITORING WITH CRETE: *C*RETE *RE*GIONAL *T*ECTONIC *E*XPERIMENT.

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Eastern Mediterranean, an area with intense tectonic activity, is of great interest for its regional oceanography. This is reflected in the large number of multi-national research projects in the area. As part of a permanent GPS array that we are currently deploying over the west and central part of the island, we intend to occupy the two tide-gauge sites at Souda Bay and Heraklion. The first one was occupied in the past and more recently, by our group as part of the CRETE project. Intense seismicity in this area and high rate geodynamic motions require that characterization of such complex deformation be done with a dense local network, preferably a permanent, continuously operating one. Continuity improves reliability and allows monitoring of the motion without any assumption about its nature. Tide-gauge monitoring has gained importance lately since (a) tectonics contaminate the inferred sea-level variations, and (b) a global network of tide-gauges with long historical records can be used effectively as satellite altimeter (TOPEX/Poseidon, GFO, Jason) calibration sites for current and future missions (a IOC/GLOSS/IGS common effort underway). The island of Crete hosts two of the oldest tide-gauges in the area with plans to soon upgrade these instruments with state-of-the-art equipment. The synergism between CRETE and the interests of the oceanographic community is the driver for this effort.

THE MEDITERRANEAN SEA GENERAL CIRCULATION AND SEA LEVEL VARIABILITY FROM NUMERICAL SIMULATIONS.

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The Mediterranean Sea general circulation and sea level fluctuations are studied by means of a high resolution numerical model. This model is capable of reproducing the seasonal fluctuations in the basin currents and changes of surface water masses in the basin, thus a representation of sea level variability due to diabatic air-sea processes and internal ocean dynamics is possible. The model results are compared with the actual knowledge of the Mediterranean Sea large scale circulation which involve the concept of sub-basin gyre cyclonic and anticyclonic circulations, boundary currents and interannual changes. To this large scale picture there is superimposed a signal of an energetic eddy field, expecially in the Algerian current regions and the Levantine basin. Interactions between mesoscale and large scale structures are evident in the large scale and instantaneous fields. The sea level variability connected with the basin gyres is large and comparable to the eddy field sea level anomalies. The barotropic and baroclinic components of the general circulation are extracted from the model simulations and related to the sea level signal. Areas shallower then 200 meters show a relevant barotropic contribution to sea level while the well known geopotential baroclinic signal is dominant in the deep, open ocean regions.

A COMPARATIVE ANALYSIS OF THE LONG-TERM SEA LEVEL CHANGE OF THE BLACK AND CASPIAN SEA

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The results of the comparison of the long-term sea level changes of the Black sea and the Caspian sea are presented. We have used the monthly mean heights of the sea level at 24 tide gauges for the time period from 1875 to 1995. The total signal which results from the volumetric changes has been evaluated for every sea. It has been shown that the patterns of the internal variability in the sea level with periods less than 19 years, are in a good agreement, if taken for different seas. These changes are linked to the climatic conditions over the continent. The long-term sea level changes with periods longer than 19 years are very much different in the individual basins. To understand the reasons of the very long term sea level fluctuations we considered the Caspian sea level fluctuations for the last 3 thousand years reconstructed from morphometric data. The power spectrum of the interdecadal variability was established. We considered the water balans model to research the reasons of the sea level fluctuation with periods less then 19 years. The model realization shown that the Black sea level fluctuations without water exchange through the Bosporus pass as so large as the Caspian sea level fluctuations.

LATE-QUATERNARY AND RECENT PROCESSES OF RELATIVE SEA-LEVEL CHANGE IN MEDITERRANEAN COASTAL AREAS

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Relative sea-level changes on the coasts of the Mediterranean Sea are affected not only by eustatic movements depending from variations in the global ocean mass and volume, but also by the interaction of several kinds of local and regional crustal movements. Local displacements, usually of gradual subsidence in coastal plains and delta areas, may become faster and not monotonic when approaching active volcanoes. Regional gradual movements due to isostatic post-glacial rebound seem to have contributed mainly to subsidence. Displacements resulting from interaction of tectonic plates are especially frequent in the Eastern Mediterranean; over the long term, they can produce trends of uplift or subsidence, either gradual and monotonic, or stepped and irregular; sudden coseismic vertical displacements, even in sequences, have often been observed; a tectonic paroxysm which affected large areas of the Eastern Mediterranean between the fourth and the sixth centuries A.D. has caused many local falls or rises in sea level. In this paper several case studies of relative sea-level change due to the above processes are discussed. Lastly, a comparison of sea-level trends on the Provençal and Tyrrhenian coasts, deduced from archaeological data and from recent tide gauge records, shows that small eustatic sea-level fluctuations of decimetric order did indeed occur in the Mediterranean area during the last two thousand years.

MEDITERRANEAN SEA–LEVEL VARIATIONS FORCED BY AIR PRESSURE

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Monthly sea levels are significantly affected by atmospheric forcing and particularly by air pressure. At time scales of months and longer, sea level is often assumed to response hydrostatically (as an inverted barometer) to air pressure forcing. However, based on monthly mean sea–level and air–pressure data, in the Mediterranean significant deviations are found from the inverted barometer response. To study the atmospherically forced sea–level variations in more detail, a simple box–model of the Mediterranean and the Black Sea is introduced. The model consists of five interconnected basins where the connection is realized by the flows of the water masses through the straits separating the basins. The driving parameter of the model is a geographical mean of low–pass filtered air–pressure time series for each basin and the model output is information of the sea level in the specified basins. The input data for the model are taken from two datasets. The sea–level data are obtained from the PSMSL, whereas the atmospheric time series are supplied by the CDIAC. The model's capability to reproduce long term sea–level variations is assessed. Moreover, a Kalman Filter can be applied to the model in order to predict sea level over several time steps.

INTERANNUAL TO DECADAL SEA-LEVEL VARIATIONS IN THE MEDITERRANEAN

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At interannual to decadal periods sea-level generally exhibits a dynamic spectrum with dominant signals changing period in time. Based on coastal tide-gauge records which, in the Mediterranean, span decades to almost a century, interannual to decadal sea-level variations in the Mediterranean are described. At these time scales, Mediterranean sea level exhibits a variability of up to 300 mm, and thus these long-period variations can affect the conditions for the occurrence of extreme events. Using atmospheric data (air pressure, temperature and precipitation), the relation between coastal sea level and climatological parameters are quantitatively determined. Long sea-level records exclusively originate from a low number of coastal tide gauges, with a strong bias towards the northern coasts. Thus, information on the spatial pattern of the sea-level variations determined from tide gauges is rather limited. However, satellite altimetry results provide the full spatial coverage over a relatively short time interval, and comparing the pattern indicated by the tide gauges with these results helps to clarify the picture. Published results from satellite altimetry are used to assess the quality of the spatial pattern in interannual sea levels deduced from coastal tide gauges.

COASTAL HAZARD IN THE MEDITERRANEAN SEA DUE TO STORM SURGES AND TSUNAMIS

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Storm surges are known to affect the Mediterranean Sea, though generally not as violently as the northern European countries, where meteorological conditions are more favourable to the passage of heavy storms. Baleari islands, the Ligurian Sea together with its western extension embracing the Côte d'Azur in France, the northern Adriatic Sea, and the northern Aegean Sea are areas where storm surges occur more frequently. Tsunamis are generated by earthquakes, volcanic explosions and landslides. Regional catalogues of tsunamis as well as the recently produced GITEC tsunami catalogue, covering the entire Europe, testify that northern Europe has been occasionally affected, but especially the Mediterranean countries such as Greece and Italy are threatened by this menace. The spectral window of tsunamis (about 10^{-2} cps) and storm surges (about 10^{-4} cps) are usually well distinct, but there are instances where high-frequency surges, sometimes called meteorological tsunamis, produce waves and tide-gauge records similar to tsunamis. Consequences of storm surges (high water level, flooding, extensive coastal erosion, etc.) and of tsunamis (destruction of offshore and of coastal structures and facilities, victims, etc.) can be extremely costly in term of economic damage and of loss of human lives. This requires the adoption of suitable policies of hazard mitigation and of coastal protection.

RESPONSE OF THE MEDITERRANEAN MEAN SEA LEVEL TO ATMOSPHERIC PRESSURE AND COMPARISON WITH THE BLACK SEA

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The response of the Mediterranean Mean Sea Level (MSL) to atmospheric pressure forcing is analyzed using 5 years of TOPEX/POSEIDON (T/P) data (Le Traon and Gauzelin, 1997). Coherence analysis between MSL and atmospheric pressure shows a significant departure from a standard Inverse Barometer (IB) effect at frequencies higher than 20 days^{-1}. At high frequencies, the phase difference between MSL and pressure is about 100° while it should be 180° for a perfect IB response. This result confirms the role of the straits of Gibraltar in limiting the water exchange at high frequencies. The MSL response is then investigated using the Candela (1991) analytical model. The model explains a large part of the variance in T/P mean sea level variations. Compared to an IB correction, it gives a smoother response with a phase delay at high frequencies. It also explains more variance in T/P MSL variations. This demonstrates that this simple model provides an improved correction of atmospheric pressure effects in T/P data. Same analysis is then performed in the Black Sea. Coherence analysis shows that the response is much more limited (up to 100 days^{-1}) than in the Mediterranean sea due to the narrowness of the Bosphorus Straits. The Candela model is then adapted to take into account the role of the wind stress on Bosphorus straits dynamics. Compared to a standard IB effect, the model provides a much better representation of the MSL response to atmospheric pressure forcing.

A TIDE AND STORM SURGE MODEL FOR THE MEDITERRANEAN SEA

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The tidal signal in most of the Mediterranean Sea is of the order of centimeters. In some areas, such as in the Northern Adriatic, the tide is of the order of half a meter and storm conditions can produce a surge of similar or larger magnitude. The total elevation due to tide and storm surge is modelled using a hydrodynamic model, which could be modified to predict the magnitude of future surges, when possible changes in mean sea level are taken into account. A high resolution two-dimensional model, forced by the equilibrium tide and the incoming tide through the Strait of Gibraltar, is used to model the tides. The four largest tidal constituents in the area, namely M_2, S_2, K_1 and O_1, are modelled simultaneously. The response of the sea to storm events is studied by adding meteorological forcing to the tidal model. Several storm periods have been identified where the conditions over Northern Italy and the Adriatic Sea have contributed to higher than expected sea levels at the coast of the North Adriatic. These are characterised by low pressure systems with associated strong south-easterly winds. One event has been studied in detail using data from meteorological observations, interpolated over the whole Mediterranean Sea, to force the model. The results, represented by time series of total elevation, tidal elevation and the surge residual, are compared with tide gauge data.

G9 Atmospheric sounding with GPS

Convener: Blewitt, G.
Co-Convener: Niell, A.E.

HIGH-PRECISION DETERMINATION OF VERTICAL CRUSTAL MOVEMENTS IN THE FRAMEWORK OF THE SELFII PROJECT

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The overall aim of the European Union SELF II project is to determine the absolute sea level and its variations and to use them in a comprehensive way to study the present interactions as well as those of the recent past among the ocean, the atmosphere and the Earth's crust and to develop appropriate models to predict future aspects. In order to be able to un- derstand true sea-level variations it is necessary to determine vertical crustal movements of the tide gauge benchmarks to an accuracy of one mm/yr or better. Continuous GPS measurements performed at tide gauge stations will provide this most important information. Within SELF II, an exper- iment has been developed which includes the use of different techniques in order to assess the capability to achieve a reliable knowledge of the vertical rates of the tide gauge benchmarks within limited time intervals. At the Medicina reference station and in the vicinity of the tide gauge at Port Corsini, near Ravenna, on the Adriatic coast, two GPS receivers have been installed in July 1996. The GPS data have been continuously acquired at the two stations since the beginning of the experiment. In Medicina, because of the nature of the experiment, several different types of data are being collected,which includes continuous gravity obser- vations by means of a superconducting gravimeter, meteorological, water table and soil moisture data. The analysis of the GPS height series has made it possible to reliably estimate the subsidence rates at both sta- tions. The height series are also examined in order to identify possible environmental influences on the observed data.

GPS-BASED ESTIMATION OF TROPOSPHERIC MOISTURE GRADIENTS

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The GPS-based estimation of tropospheric delay gradients at a given site was shown recently to improve the day-to-day repeatability of the estimates of the site position vector [Bar-Sever et al., 1998]. The estimated delay gradient is a superposition of a hydrostatic delay gradient due to horizontal pressure and temperature gradients, and a "wet" delay gradient due to horizontally asymmetric distribution of moisture. The difficulty in separating the hydrostatic and wet gradients has complicated efforts to validate the GPS-based estimates. In this paper we present an algorithm for the separation of the hydrostatic and wet components of the estimated gradients using pressure and temperature fields from objective analysis. The accuracy of that algorithm, as well as the accuracy of the GPS estimates are assessed at several sites where a water vapor radiometer is collocated with a GPS receiver, and where dense pressure and temperature fields from objective analysis are available. This allows us to validate the estimates of moisture gradients as a new GPS product which significantly enhances the utility of ground-based GPS to weather forecasting applications.

Bar-Sever, Y.E., P.M. Kroger and J.A. Borjesson, Estimating Horizontal Gradients of Tropospheric Delay with a Single GPS Receiver, to appear, J. Geophys. Res., 1998

THE EFFECT OF TEC ON ANTARTICA GPS MEAUSUREMENTS

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In this paper we deal with the effect of ionospheric layers on GPS carrier phase measurement and relative positioning. Ionospheric refraction introduce errors on baseline solution value that cannot be completely solved with the dual frequency technique that consider the ionosphere as an undisturbated region (geometric effect) with an associated constant vertical gradient of Total Electron Content (TEC). Non-geometric effects also play an important role, mainly in equatorial and polar regions where, due to magnetic storms and solar activity, severe ionospheric conditions occur causing small-scale irregularities, like scintillation phenomena, which gives difficulties in ambiguity resolution. Moreover this is a particularly true in Antarctica regions. With the aim to model and to reduce part of this effect we have computed and compared different TEC value from different method (GPS code and phase measurements, baseline length method, zero-baseline method and "Bernese" ionospheric parameters estimator). Then the effects of different computed values on relative position (coordinates of points) or baseline length value were investigated.

G9

USAGE OF GREF-PERMANENT NETWORK RESULTS FOR GEODESY AND METEOROLOGY

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Since middle of 1996 the BKG computes daily solutions for a set of German and European permanent GPS stations using the Bernese software. The EUREF permanent network is to be densified by a set of up to twenty stations in Germany currently under installation. Presently about twelve stations are operating. Results for a subset of the EUREF network from the BKG processing centre are submitted to the EUREF Analysis Centre in Bern to be included to the European weekly EUREF solution. The BKG processing is used further to produce sets of tropospheric zenith delay parameters in two hour intervals. These are combined and compared to the Wettzell Water Vapour Radiometer of BKG operating since October 1997. In a joint research project with the German Weather Service the potential use of the vertical integrated water vapour (IWV) content as derived from the tropospheric zenith delay for the improvement of numerical weather forecast is studied. As a first step, the derived GPS-IWV is compared to IWV derived from weather forecast models and the influence of ancillary numerical model data used in the derivation of GPS IWV is studied. This paper presents results of a test phase selected for a feasibility study.

THE WAVEFRONT PROJECT ON GPS WATER VAPOUR ESTIMATION

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WAVEFRONT is an EC funded collaborative project between four European institutions in Spain, Sweden, Switzerland and the UK. The three year project started in September, 1996, under the EC Environment and Climate work programme. WAVEFRONT aims to develop the potential for using ground-based GPS to estimate the variable water vapour content of the atmosphere. More specifically, the project aims to validate the accuracy and temporal resolution of GPS water vapour estimation, by comparison with ground-based Water Vapour radiometers (WVR?s) and radiosondes. The associated error sources involved within the GPS processing, the a-priori statistics, conversion constants applied and network processing strategies are examined, in addition to a comparison of three GPS processing software packages (BERNESE, GAS and GIPSY). A tomographic analysis is also undertaken in addition to a feasibility study for estimating atmospheric water vapour on a near real-time basis. The archiving of one hour averages of atmospheric water vapour is being performed at approximately forty European IGS stations, ultimately to obtain a continuous two year water vapour time series. Results from the first year of the WAVEFRONT project are presented.

IONOSPHERIC SIGNATURE OF SURFACE MINE BLASTS FROM GLOBAL POSITIONING SYSTEM MEASUREMENTS

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In July and August 1996, 3 large surface mine blasts (1.5 Kt each) were detonated at the Black Thunder coal mine in eastern Wyoming. As part of a seismic and acoustic monitoring experiment, we deployed 5 dual-frequency GPS receivers at distances ranging from 50 to 200 km from the mine and were able to detect the ionospheric perturbation caused by the blasts. The amplitude of this perturbation is comparable to that reported after the much larger (M6.7) Northridge earthquake of January 17, 1994 (Calais and Minster, 1995). This indicates that surface explosions are much more efficient sources of ionospheric perturbations than even large shallow thrust earthquakes. The spectrum of the observed signals is primarily concentrated in the 5-minute band, which appears to correspond to a gravity mode, in agreement with previous observations made after nuclear explosions and volcanic eruptions. The relatively small signal-to-noise ratio of the perturbation can be improved by slant-stacking the electron content time series recorded by the different GPS receivers taking into account the horizontal propagation of the perturbation. Using a one-dimensional stratified velocity model of the atmosphere we show that linear acoustic ray tracing fits arrival times at all GPS receivers. We interpret the perturbation as a direct acoustic wave caused by the explosion itself.

A SLIDING-WINDOW PRECEDURE FOR SUPER NEAR REAL-TIME CONTINOUS GPS WATER VAPOR ESTIMATION USING PREDICTED ORBITS

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Weather forecasting models may be benefit from the spatial distribution of precipitable water vapor content derived from GPS observations. A continuous GPS processing procedure is designed for delivering such water vapor estimates at very high turn-around rate in a sliding window fashion. The sliding window scheme is devised to process a session of data and move forward a step at a time with session length (window width) longer than step size. This scheme improves the precipitable water vapor estimates at the session boundary that are normally poorly determinated. Results from tests of various window widths and step sizes using predicted orbits are compared in terms of efficiency and accuracy against results from well-developed standard procedures using precise orbits. The requirements and limitations of our approach, as well as the scheme of rejecting poor orbits, are also discussed.

USE OF GPS FOR ESTIMATING WATER VAPOUR ATTENUATION ON SATELLITE-EARTH LINKS AT MILLIMETEE WAVELENGTHS

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It has been shown that measurements from a stationary GPS receiver can be used to estimate the Integrated Precipitable Water Vapour (IPWV) content of the atmosphere. At millimetre wavelengths water vapour contributes significantly to the total attenuation on a satellite-earth link. Cloud is also another strong contributor to attenuation, and previous studies have noted a clear correlation between water vapour and cloud attenuation. Therefore it is important that water vapour content in the atmosphere be accurately measured and GPS provides an excellent tool to perform this task.
This presentation details GPS observations taken over a 9 month period at the University of York. Processing of the GPS data for zenith total delay was performed by GIPSY-OASIS II, from JPL, using the precise point positioning strategy. The GPS IPWV estimations have been compared to measurements derived from temperature and humidity profiles, obtained using radiosondes, from two sites approximatley 160 km away. In both cases, the agreement with the GPS estimated IPWV has been good. Attenuation at zenith of the atmosphere is measured indirectly by a 93 GHz radiometer, which is co-located with the GPS receiver at York.

ATMOSPHERIC IMAGING INVOLVING GNSS OCCULTATION: A QUANTITATIVE STUDY

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Global Navigation Satellite System (GNSS) based radio occultation, as a standalone technique, delivers near-vertical profiles of atmospheric bending angles, refractivity, pressure, temperature, and humidity. The potential of ground-based GPS measurements for accurately estimating vertically integrated atmospheric water vapor has been demonstrated recently (e.g., Rocken et al., *J. Geophys. Res.*, **97**, 15787-15801, 1992). Height resolving imaging of atmospheric water vapor becomes feasible, when occultation data are combined with ground-based GNSS or spaceborne passive sounder data ("true" imaging), or with atmospheric model information ("model-assisted" imaging). Having formulated space-time and co-location requirements for "true" and "model-assisted" imaging, we present quantitative results on space-time coverage based on realistic geometry simulations which have been performed for several Low Earth Orbit (LEO) satellite scenarios. Also, imaging techniques are currently developed, and first results using simulated GNSS-based water vapor measurements from LEO and ground will be discussed.

ATMOSPHERE/IONOSPHERE SOUNDING USING GPS RADIO OCCULTATION MEASUREMENTS ONBOARD CHAMP

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After giving a brief introduction to the general CHAMP satellite mission concept the talk is focussed on the use of GPS radio occultation measurements for probing the vertical structure of troposphere/stratosphere and ionosphere/plasmasphere systems. This includes the discussion of the corresponding software architecture and planned analysis procedures. Operational use of the CHAMP data is foreseen both for atmospheric as well as for ionospheric data products. Preliminary results obtained after applying experimental software tools on GPS/MET data are briefly discussed.

AN END-TO-END OCCULTATION SOUNDING SIMULATOR: OVERVIEW AND EXEMPLARY RESULTS

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A software tool has been developed, as an international European effort, which is capable of end-to-end simulation of the GNSS-based radio-occultation technique and processing of real occultation data. The major aims of the tool, named EGOPS (End-to-end GNSS Occultation Performance Simulator), are: (i) mission analysis/planning for GNSS (GPS/GLONASS) receivers at LEO (Low Earth Orbit) satellites (geometry, coverage, statistics for given GNSS/LEO/ground-station constellations), (ii) simulation of occultation observations (forward modeling of signal propagation through the atmosphere-ionosphere system plus effects of the receiving system), (iii) processing of simulated and observed occultation data (inversion from phases and amplitudes to atmospheric profiles). An overview on concept and capabilities of EGOPS is given. In particular, exemplary EGOPS results for the major aims (i) – (iii) are shown and discussed, which are directly related to currently open questions in the field. Finally, plans for future advancements of EGOPS are outlined.

SIMULATION OF FULL DATA ASSIMILATION CYCLE COMPARISON

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The possible impact of GNSS occultation data on model results, as well in climate modelling as in numerical forecasting, has been simulated in a twin experiment. The comparison between different assimilation heights are compared with a model run representing a 'true' development and another run, only driven by surface data. The results of this runs are showing a remarkable progress in modelling the geopotential height and temperature. These are the most important parameter describing the large scale circulation and so an good indicator for the improvement by GNSS occultation data. Due to the experiment setup, a global data coverage is assumed.

MEASUREMENTS OF WATER VAPOR IN THE ATMOSPHERE: // COMPARISON OF RADIOSONDE, WATER VAPOR RADIOMETER, GPS, AND VLBI

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The accuracy of GPS as an instrument for measuring the integrated water vapor content of the atmosphere has been assessed by comparison with concurrent observations made over a 15 day period by radiosonde, microwave water vapor radiometer (WVR), and Very Long Baseline Interferometry (VLBI). Estimates of zenith wet delay (ZWD) by GPS measurements with Dorne-Margolin choke ring antennas were found to have a strong dependence on the minimum elevation of data included in the solution, and the best agreement with the collocated WVR and VLBI measurements was for minimum elevations below 15 degrees. Temperature profiles obtained with the Vaisala radiosondes differed significantly from those of the U.S. National Weather Service with differences in ZWD as large as 40 mm (6 mm of precipitable water vapor) for total ZWD of 250 mm. WVR, GPS, and VLBI agreed within approximately 6 mm of ZWD (1 mm of PWV), while the radiosondes averaged approximately 75% of the ZWD measured by the other three techniques. Elevation dependent phase errors for the GPS antenna/mount combination can produce PWV errors of greater than 5 mm over a few hour period for typical GPS satellite coverage.

ANALYSIS OF TEC VARIATION FROM GPS MEASUREMENTS

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GPS observations of Polish IGS stations were used for ionospheric TEC variation determination at middle latitudes. Absolute TEC has been routinely estimated from code GPS measurements over 1995-1997. We present the analysis of day-to-day diurnal, seasonal and storm-time variations. Variations of TEC are discussed with one of foF2 at Warsaw. It was found that at minimum solar activity in seasonal behaviour of TEC the distinct minimum may be seen on December-January at the same time, the expected equinoctial maximum is poor. Using TEC measurements and data of foF2 the ionospheric slab thickness (τ) was determined. That parameter is useful for analysis of day-time ionosphere. The determined night slab thickness is very changeable because the night TEC is comparable with errors of GPS measurements. The behaviour of measured TEC and τ have been compared with IRI model. We also present the storm-time effects in ionosphere. The major feature during storm is significant TEC increase (positive phase of storm). For winter the increase makes up factor of 1.5-3.0. The negative phase of storm is poorely distinctable.

ON THE IONOSPHERE CALIBRATION IN ATMOSPHERIC LIMB SOUNDING

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Elimination of the ionospheric contribution to atmospheric delays in satellite to satellite limb sounding is very crucial in order to obtain accurate pressure and temperature profiles above the tropopause. The so called ionosphere free combination of the L1 and L2 carrier phases is not sufficient because of the non-negligible bending of the two ray paths. Due to the dispersive nature of the ionosphere the L1 and L2 signals will follow slightly different paths, giving rise to an ionospheric residual, referred to as the splitting-bending term. Also higher order ionospheric terms contribute to the residual, but the splitting-bending term is the most influent. Vorob'ev and Krasil'nikova (1993) introduced the idea of a linear combination of the L1 and L2 bending angles. This method gives the better results in most cases, but still suffers from various approximations, one of them being the assumption of spherical symmetry in the ionosphere.
Heading towards solar maximum the need for a better model-independent ionosphere calibration scheme will become evident. Also, to exploit the potential accuracy of future GPS receivers it is necessary to find a better correction of the ionosphere than the ones used at present.
In a simulation study we have estimated the residuals for various conditions in the ionosphere, and we show how both the splitting-bending and the second order ionosphere effects can be mitigated using measurements of the satellite to satellite Total Electron Content (TEC).

MULTIPATH INFLUENCE ON ATMOSPHERE - IONOSPHERE PROFILING.

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The main difficulties of using GPS/MET system for atmospheric and ionospheric profilling are the multipath in propagation media. The basic causes of multipath propagation are the reflection/scattering from/on the protonosphere-ionosphere-atmosphere irregularities and the reflection from the Earth rough surface. The unregular character of such processes is connected with the spaceborn flight geometry and Earth surface roughness. The multipath leads to the disturbations on the recording parameters profiles - doppler shift or angle refraction. For the doppler profiles this disturbations are the beating between different rayes. Moreover, the beating frequency is depended on the spaceborns positions and orbits. This frequency reaches above some Hz, as it was founded by END-TO-END modelling. The beatings can appear at the height above 20 km, this fact of numerical simulation is verified by many experimental data - the "splashes" appear on the doppler altitude profile. This effect has great influence on ionospheric profiling, because the beating frequency reaches value above or even more regular effects in some cases.

G10 Satellite and airborne gravimetric and altimetric techniques

Convener: Forsberg, R.
Co-Convener: Haagmans, R.

AIRBORNE GRAVIMETRY AND ALTIMETRY CAMPAIGN IN THE AZORES REGION

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In the scope of the european project AGMASCO, an airborne gravimetry and altimetry campaign has been realized in the Azores region in October 1997. The system used has been developed by the AGMASCO group and installed in a CASA Aviocar aeroplane of the portuguese Airforce.The system was specially designed to operate in coastal and shelf regions where satellite altimetry fails to give the desired information about sea surface topography. The Azores region, lying in the confluence of three main tectonic plates, the Azores Triple Junction, is considered a natural laboratory for earth sciences research. The sea bottom topography shows peculiar features with active volcanism being detected. Also from the oceanographic point of view the region presents very interesting characteristics which are not yet well known. In this campaign a survey of the Azores area from latitude 37 to 40 N and longitude 25 to 31 W was realized. Shipborne measurements were also done along some of the airborne profiles by the oceanographic vessel of the University of Bergen. Results from satellite altimetry, airborne and shipborne measurements will be compared and combined to improve geoid and SST definition in this region. In the paper results obtained so far with this Azores campaign are presented and discussed. The system architecture is also refered.

ASSESSMENT OF GRAVITY FROM ERS ALTIMETRY AND AIRBORNE GRAVIMETRY IN POLAR SEAS

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ERS satellite radar altimeter waveform data have been used to produce high resolution gravity fields for all Arctic seas south of 82 degrees north including permanently ice-covered seas (Laxon and McAdoo, Science, 1994; Eos, 1997) and for Antarctic Seas (McAdoo and Laxon, Science, 1997). The Naval Research Laboratory has used GPS kinematic carrier phase positioning to make revolutionary airborne gravimetric surveys of the Arctic (Brozena et al., IAG Symp, v 117, 1997). We have compared selected NRL airborne gravimetric results in the Arctic with the ERS altimetric gravity and obtained excellent results. Selected comparisons in the Canada Basin show an rms agreement of better than 4mGal. Also, spectral coherency analyses show that these two results are coherent to wavelengths as short as 30 km. This implies that these two independent techniques both do a very good job of resolving, spatially, the details in the gravity field. This resolution allows detection of gravity anomalies that reveal tectonic details which are imprinted in the seafloor including an apparent extinct spreading ridge in the Canada Basin.

Airborne Gravimetry and Altimetry in North Greenland and Fram Strait - NORDGRAV '97

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An airborne gravity and altimetry system has been developed and implemented in the research aircraft Polar-2 of the Alfred Wegener Institute (AWI) by the AGMASCO group. This installation is designed to operate in regions which are not covered by altimetry satellite orbits, therefore local gravity structures and seasurface topography are not resolved by satellite.
The AWI, the Danish National Survey and Cadastre and the University of Bergen have carried out a gravity and altimetry survey across Fram Strait and in the north of Greenland during summer '97: NORDGRAV '97.
The main objective of these experiment was to transfer this in lower latitude tested airborne technique to polar regions. Gravity anomalies over the Spitsbergen Fracture Zone, Yermak Plateau and Morris Jessup Rise were mapped.
Simultaneously to NORDGRAV '97 shipborne gravity and oceanographic measurements were carried out on RV Polarstern. First results from the airborne measurement and comparision to the shipborne measurement will be presented.

COMPARISON OF VARIOUS CONFIGURATIONS OF ACCELEROMETERS FOR STRAPDOWN AIRBORNE GRAVIMETRY

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For strapdown airborne gravimetry, various sensors are being developed on the basis of inertial grade accelerometers. Sensor configurations of one accelerometer or triads of non-orthogonal or orthogonal accelerometers, either in skew ("umbrella") or vertical / horizontal / horizontal configuration all have specific characteristics and requirements in the context of system embedding. From both theoretical considerations and practical experiences including numerical results, the various configurations are discussed.

AIRCRAFT ACCELERATION FROM GPS FOR AIRBORNE GRAVIMETRY: A COMPARISON OF TECHNIQUES

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The performance of an airborne gravity system at a given resolution is a function of the accuracy of each of it's components at that resolution. As the resolution of a DGPS/INS airborne gravity system is increased, the accuracy of the GPS-derived aircraft acceleration is a critical factor limiting it's accuracy. Higher accuracy short wavelength information will become available when the resolution of GPS-derived acceleration is improved. GPS accuracy in the corresponding frequency range is a function of the measurement errors and the modeling and estimation techniques that are used. The objective of this paper is to evaluate the influence of these effects as the upper limit of the frequency band of interest is increased and to suggest suitable methods of determining vehicle acceleration from GPS for airborne gravimetry. This will be done in three parts. First, a comparison will be made between the results obtained by estimating the position and velocity of the aircraft using different kinematic models. Constant velocity and constant acceleration models will be applied and compared. A carrier phase derived Doppler will also be used to estimate vehicle velocities. Second, since the acceleration of the aircraft will be derived by differentiating the estimates of its position and velocity, several methods of differentiation will be considered. They include the differentiation of interpolating polynomials implemented as a Savizky-Golay smoothing filter, the differentiation of a natural spline approximation and the application of several digital FIR and IIR differentiating filters. Third, the combination of estimates of vehicle acceleration obtained using several ground-based DGPS reference stations will be considered. Data from flight tests flown in the Canadian Rocky Mountains will be used for this evaluation. The assessment of the accuracy of each method will be based on comparing the results with an independent gravity field reference. Results will be analyzed in flight lines where the vehicle dynamics are relatively constant and in turns where the dynamics are considerably higher.

THE EUROPLATFORM EXPERIMENT: TESTING PRECISE, LONG-RANGE KINEMATIC GPS FOR REMOTE-SENSING

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Surveys of large areas using GPS to register or correct altimetric, gravimetric, photogrammetric, or sonar data often take place far from GPS reference sites. In order to test the long-range accuracy of kinematic GPS, the Europlatform experiment was conducted in the North Sea, on the 17 of December, 1996. Dual-frequency carrier-phase and pseudo-range were collected at 1 Herz, for almost 5 hours, simultaneously at the platform (off the coast of Holland) and at a number of sites in different European countries, including some EUREF sites that were used as fiducial stations. The other fixed sites were tied to the combined EUREF solution for week 884. Distances from the platform to the various sites ranged from 40 km to 1300 km. All data were post-processed using software developed by the first author. Non-fiducial station and rover coordinates were nearly free-adjusted, with a priori sigmas of 100 m per coordinate. Carrier-phase "L3" biases were estimated as real numbers. The resulting trajectories were accurate to <10 cm in both r.m.s. and mean (or less than one part in 10^7 of the distance to the nearest receiver), using either the (final) IGS SP3 orbits, or the broadcast orbits adjusted together with the trajectory.

FEASIBILITY STUDY OF MULTIKILOHERTZ SPACEBORNE MICROLASER ALTIMETERS

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Various laser altimeters have recently operated successfully in space from both Earth and Mars orbits. Desirable features of future laser altimeters include more contiguous coverage (i.e. higher repetition rates and/or wider swaths) and higher spatial resolution in both the transverse and vertical dimensions. At the same time, there is a need to develop prime power efficient devices for spaceborne use, and these two contrary goals tend to push the hardware characteristics in opposite directions. NASA has recently been developing an eyesafe, fully automated Satellite Laser Ranging system, "SLR2000", which is designed to track artificial satellites equipped with passive optical retroreflector arrays. This system utilizes multikilohertz low energy (~100 μJ/pulse) passively Q-switched microlaser transmitters, pixellated array detectors for simultaneous ranging and pointing angle correction, and special "correlation range receivers" which can identify and recover extremely weak reflected signals from the dominant daylight noise background (S/N< 10^{-3}) through post-detection Poisson filtering techniques. We investigate, through theoretical analysis and computer simulation, the potential utility of this innovative technology in developing compact, low prime power, high spatial resolution laser altimeters designed to operate from Earth or planetary orbits.

GEOID AND SEA-SURFACE TOPOGRAPHY DETERMINATION BY AIRBORNE TECHNIQUES

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Airborne altimetry has the same potential as satellite altimetry to define the instantanous sea-surface, but in addition airborne gravity may be used to determine the geoid. By combining the two techniques it is in principle possible to separate the oceanographic sea-surface topography from the geoid. In the paper the general principles of airborne geoid determination will be reviewed, and the methods applied to AGMASCO data from the Skagerrak region. Resulting geoid undulations will be evaluated by comparisons to GPS-levelling onshore, and to Topex/ERS altimetry and oceanographic models at sea.

GEOID REFERENCED ELEVATION MODELS AND ORTHO-RECTIFIED IMAGE MAPS FROM SYNTHETIC APERTURE RADAR

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The objective of this paper is to introduce and describe the concept of using strapdown airborne gravimetry to reference mapping products derived from Interferometric Synthetic Aperture Radar (IFSAR) to the geoid. Calgary-based Intermap Technologies Ltd. is a digital mapping company that focuses on providing digital elevation models, and ortho-rectified images using an interferometric radar system called the STAR-3i. Intermap Technologies Ltd. in partnership with the University of Calgary has developed a product capable of providing geoid referenced digital elevation models and ortho-rectified images.

Using the IFSAR technology, the STAR-3i provides a new generation of airborne radar digital elevation models and ortho-rectified image maps. The STAR-3i consists of two X-band radar antennas mounted on a LearJet36. The data, which is collected simultaneously for the two antennas, is combined by a digital correlation process to extract terrain information. STAR-3i uses integrated DGPS/INS navigation results to obtain highly accurate positioning and orientation control.

The University of Calgary has developed software to extract gravity disturbance information from the DGPS/INS data collected in the STAR-3i system. Using the gravity information, a precise relative geoid is determined for the flight area. By combining this geoid with the EGM 96 geopotential model, the mapping products derived from the STAR-3i system can be directly referenced to the geoid.

The STAR-3i system, and the method of extracting the geoid from the integrated DGPS/INS data will be presented. An analysis of the accuracy of the system will also be given. Based on a preliminary analysis, for a flight elevation of 6000 meters and flight speed of 700 km/h, the accuracy of the geoid reference is better than 1 metre RMS globally, and better in some local areas. The accuracy of the STAR-3i elevation map is 1 to 2 metres RMS.

A MEAN SEA SURFACE DEDICATED TO OCEAN STUDIES: GLOBAL ESTIMATION

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Topex/Poseidon (T/P), GEOSAT, and ERS-1 improved altimetric dataset are used to estimate a mean sea surface (MSS). This MSS is dedicated to oceanography, focusing on the accuracy of the mean sea height along the satellite ground tracks. The 3-years T/P accurate (1.2 cm rms) mean profile is processed to reference the MSS. A two-year ERS-1 mean profile is calculated by merging phase C and G dataset, with a 1.6 cm rms accuracy. The two-year GEOSAT mean profile is 2 cm rms accurate. These two profiles are adjusted to T/P. The data of the two 168-day ERS-1 geodetic cycles are also used, to provide a global 8 km resolution to the MSS. For all the ERS-1 data, the ocean variability is removed from the sea surface height by subtracting the T/P sea level anomaly, then the orbit error are also reduced by spline-fitting with T/P arcs, allowing a 6.5 cm rms accuracy. EGM96 geoid is removed to the data. A suboptimal inverse technique is applied to estimate the MSS from these residuals, on a 1/16° grid. This technique take into account the long wavelength biases on altimetric arcs and also the oceanic variability noise. The MSS is validate first by analyzing discrepancies with the mean profiles ; e.g., less than 0.8 cm rms and 0.1 cm/km rms with the T/P mean profile in the North East Atlantic. Its accuracy is improved compared to other MSS, particularly at small scales. And there are about 4.7 and 5.2 cm rms discrepancies with OSU95 MSS and the GRGS MSS respectively, in our test area.

INTRODUCTION OF OCEAN CIRCULATION MODEL INFORMATION IN GLOBAL GEOPOTENTIAL SOLUTIONS: PRELIMINARY RESULTS

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The two-year mean (1993-1994) Dynamic Ocean Topography (DOT) field implied by the POCM_4B circulation model was used to develop normal equations for DOT, in a surface spherical harmonic representation. A corresponding Mean Sea Surface derived from TOPEX/POSEIDON and ERS-1 data was used to compute corresponding normal equations for gravitational harmonic coefficients and for DOT coefficients. These two sets of normals were combined with normals from satellite tracking data analysis and from surface gravimetric data analysis. Several combination solutions were developed in this fashion, by varying parameters such as the maximum degree of the estimated DOT and the relative weights of the different data. The solutions were evaluated in terms of orbit fit residuals, GPS/Leveling-derived undulations, and *independent* DOT information from *in situ* hydrographic sources.

The results from these tests will be discussed with particular emphasis on the weighting of the DOT information implied by POCM_4B. Directions for future work and problematic areas will be identified.

RECOVERY OF THE GLOBAL MARINE GRAVITY FIELD FROM MULTI MISSION SATELLITE ALTIMETRY

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Satellite altimetry from the GEOSAT and the ERS-1 geodetic missions provide altimeter data with a very dense coverage. Hence, the gravity field may be recovered very detailed. Satellite altimetry from the 35 days repeat cycle mission of the ERS satellites and, especially, from the 10 days repeat cycle TOPEX/POSEIDON satellite mission provide accurate mean sea surface heights along the ground tracks of those missions. In this study the global marine gravity field has been derived using the altimetry from the geodetic missions. This was done in small cells covering the worlds ocean using advanced techniques for crossover adjustment, gridding by local collocation, and conversion of sea surface heights into gravity by FFT. Then averaged sea surface heights of the repeat missions were used to construct an accurate mean sea surface. To enhance the resolution of the mean sea surface the altimetry from the geodetic missions was utilized. Marine geoid heights derived from the altimetric gravity was used for this task. The advantage of such a procedure is that inconsistences along the edges of the small cells may be avoided.

ALTIMETRIC GRAVITY ANOMALIES BASED ON GEOSAT AND ERS-1 GEODETIC MISSION DATA

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Two areas were selected for the computation of high-resolution marine gravity fields, the first one along the Mid-Atlantic Ridge (30.5°S - 36.5°S) and the second one around the Azores (41°N - 36°N). For the Geodetic Missions of ERS-1 (Apr94 till Mar95) and Geosat (Apr85 till Sep86) sea surface slopes in along-track and in direction of the crossing tracks were derived at each single 1-Hz altimeter point. The slopes then were converted to east and north vertical deflections which were interpolated at a regular grid with 2' × 2' resolution and low-pass filtered. Finally the gravity anomalies were calculated from the deflection grids by using a 2-dimensional Fast-Fourier transformation (FFT). For the first test site two separate solutions based on ERS-1 and Geosat GM data were generated, as well as a solution based on the combination of these data. Quality tests were performed by comparing the altimetric derived anomalies with anomalies from the gravity maps of several authors, and in addition with validated and adjusted shipboard gravity data. For the second area comparisons were performed with first results of airborne derived gravity anomalies.

HIGH-RESOLUTION AIRBORNE GRAVITY SURVEY OF SKAGERRAK

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As part of the EU-MAST airborne geoid determination project AGMASCO, an airborne gravity survey has been carried out over the Skagerrak region between Denmark and Norway. The region has several geologically distinct gravity anomalies due to salt domes and volcanic intrusions, and therefore is a good region for testing the quality and resolution of airborne gravity. In the paper the survey and processing techniques are outlined, along with the principles of an improved error model for the used Lacoste and Romberg ?Ultrasys? airborne gravimeter. The airborne gravity measurements are evaluated by cross-over statistics and upward continuation of high-quality ground data, indicating an accuracy of 2 mgal at a resolution of 6 km for the airborne data.

DEVELOPMENT OF THE END-TO-END CLOSED LOOP SIMULATION FACILITY FOR ESA'S GRAVITY EXPLORER GOCE

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GOCE (Gravity field and Steady-State Ocean Circulation Explorer) is one of the four selected ESA Earth Explorer Missions which will enter a Phase A (System Baseline Definition Phase). The main objective of GOCE is to determine the earth's gravity field with a high resolution and a high and homogeneous accuracy. Disciplines like Oceanography, Geophysics and Geodesy will greatly benefit from such improved gravity field knowledge. GOCE will utilize two space techniques: Satellite to Satellite Tracking (SST) by means of an on-board GPS/GLONASS receiver, for orbit determination and retrieval of the long and medium wavelength components of the gravity field, and Satellite Gravity Gradiometry (SGG) for the retrieval of the gravity field up to the short wavelengths. The 3-axis SGG instrument is a new technological development. Presently there are two concepts for the gradiometer: the capacitive gradiometer operating at room temperature and the more accurate inductive gradiometer operating at cryogenic temperature. The objective of the simulation facility is to couple all system aspects of satellite, including attitude and orbit/drag control, and SGG instrument parameters with the environment (orbit, gravity field, atmosphere, etc). As a typical follow-up for classical error propagation methods, such a simulator will allow to rather realistically study the sensitivity of the higher level data products to instrument and satellite subsystem errors. We will show the development scheme of the simulator together with the preliminary results for the sensitivity of the retrieved geoid to SGG test mass misalignments and scale factor mismatches.

SPACE-BORNE GRAVITY GRADIOMETER

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We propose a new type of the satellite gravity gradiometer. The gravity gradiometer is based on a peculiarity in the magnetic interacting of superconducting solenoids in the weightless state. The energy of the magnetic interacting of a pair of superconducting solenoids in weightless state with persistent currents, generally speaking, has the minimum at some distance between the solenoids. At this distance the solenoids are in weak equilibrium stable condition. This solenoids, coupled by "magnetic spring", is a nonlinear oscillator with a low ($0.0001 - 0.1Hz$) resonant frequency. By using an electronic damper the device can works as a null-detector of the tidal accelerations of the solenoids, caused by the second derivative of the Earth's gravity. (The sensitivity up to $10^{-5}E$ can be realized) The gravity gradiometer can be used in geophysical survey, inertial navigation, satellite geodesy . (A prototipe is the space-based gravitational- wave detector: L.V.Verozub , Gen.Relat. and Gravit. 1996, No 1, 77).

The Computation of Mean Sea Surfaces and Marine Gravity Anomalies Using Satellite Altimeter Data from TOPEX/ POSEIDON, ERS-1 and GEOSAT Missions

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The mean sea surfaces have been computed on 5' x 5' and 2' x 2' grid using satellite altimeter data from the TOPEX/POSEIDON, ERS-1 and GEOSAT missions. The data used includes 3 years of TOPEX/POSEIDON data (Cycles 9 to 119), 1.5 years of ERS-1 35-day repeat data (Cycles 1 to 18), 2 years of GEOSAT ERM data (Cycles 1 to 42), 10 months ERS-1 Geodetic Mission (168-day repeat) data, and 18 months GEOSAT GM data. The ocean variability effect to the mean sea surfaces was reduced by an iteration procedure. The ocean dynamic topography model POCM4B was removed from the mean sea surfaces to obtain the geoid undulations over the ocean. Based on these mean sea surfaces implied geoid undulations the marine gravity anomalies were computed on 5' x 5' and 2' x 2' grid using the inverse Stokes' integral. The gravity anomalies were also computed from the mean sea surfaces CSR95 and OSU95 implied geoid undulations using the inverse Stokes integral. Comparisons between ship gravity data and the gravity anomalies from the altimetry will be presented. The comparisons between the altimetry gravity anomalies derived by various groups using different techniques will also be shown.

ALTIMETRIC STUDY OF SEA LEVEL VARIATION ON THE MEDITERRANEAN ALONG ERS AND TOPEX CAMPAIGNS

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Traditionally global sea level changes were estimated from tide gauge measurements collected in several geographic places, mainly harbours, over present and last century. However, the main problem with these temporal series is that they measure only the sea level change compared with a fixed reference point, frequently deficiently related to the global geodetic nets.Satellite altimeter mission as TOPEX-POSEIDON, ERS-1 and ERS-2 should, in principle, provide improved measurements of any absolute sea level change compared with a precise reference frame realised through the assigned coordinates of the satellite tracking stations in a global geodetic system, whose origin coincides with the earth centre of mass. We present in this communication the sea level variation time series in the cross points of the Topex-Poseidon satellite over the Mediterranean and Black sea areas, as computed from AVISO MGC series, comparing the seseries with the ones obtained with ERS satellites and selected tide gauges in the area.

G11 Recent advances in precise geoid determination methodology

Convener: Tziavos, I.N.
Co-Convener: Vermeer, M.

IMPROVING THE GEOID ACCURACY BY ADOPTING THE REFERENCE FIELD

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In the frame work of the Austrian Geoid 2000 project, the accuracy of the geoid has to be enhanced. One of the possibilities is to adopt the used reference field. The used traditional remove/restore technique has the ambiguity of the doublication of removing the effect of the topography and its compensation for the data window. To avoid such a doublication, the effect of the topographic-isostatic masses for the used fixed data window has been subtracted from the reference field yielding an adopted reference filed. This adopted reference field has been used for the remove/restore technique. The paper shows a comparison between the geoid computed by the adopted reference field and that computed by the traditional reference field.

GRAVITY FIELD RECOVERY FROM AIRBORNE GRAVITY GRADIOMETER DATA USING COLLOCATION AND TAKING INTO ACCOUNT SYSTEMATIC ERRORS

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Least squares collocation is a very efficient method for Geodetic studies, especially in the case that the noise characteristics of the data are known. In many earlier applications the errors affecting the data were considered uncorrelated, mainly due to the difficulty in estimating the systematic character of such kind of errors. In this study, error covariance functions of airborne gravity gradiometer data are estimated by comparing model covariance functions with empirical covariance functions of the gravity gradiometer data. The model covariance functions were estimated from accurate surface gravity data and continuated upward to the height of the airborne measurements using the covariance propagation law. The estimated error covariance functions were modeled as finite ones and used as an additional information for the prediction of gravity anomalies from gravity gradiometer data. The assessment of the prediction results was made by comparing the predicted values with observed gravity anomalies.

INVESTIGATIONS OF THE EARTH FIGURE BY GRADIENTOMETRIC DETERMINATIONS

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A possibility of an application of the vertical and horizontal gravity gradient anomalies to the construction of the boundary value problem is presented in the paper. The kernel integral functions are given, in analogy to the Stokes' and Vening-Meinesz functions. Presented approach ought to be applied in geodetic practice taking into account recently obtained precision of geoid and height differences determinations by satellite and terrestrial data. Results of gradientometric determinations on the geodetic test field of the Warsaw University of Technology near Grybów in sub-mountain area are cited in the paper. The comparison beetwen gravimetric and GPS-levelling for this region is given.

A NEW, MORE ACCURATE GEOID FOR CROATIA

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A new geoid of Republic of Croatia is obtained for a range of purposes, particularly for precise height definition using GPS technology and for planned modeling of Adriatic Sea bathymetry. The calculation of geoid undulations is accomplished by combining gravity, altimetry and GPS/leveling data as well as a global geopotential model, and using collocation and FFT techniques in a remove-restore procedure. Taking benefit of new gravity and altimetry data resulted in significantly more accurate geoid model for Croatian territory, what can be seen in comparison with prior Croatian geoid solutions, new European EGG97 geoid and GPS/leveling data as well.

DIFFERENT WAYS TO HANDLE TOPOGRAPHY IN PRACTICAL GEOID DETERMINATION

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In this paper two different methods of how to handle topography in geoid determination is investigated. First method employs the RTM remove-restore technique and yields the quasigeoid, whereas the second method is the classical Helmert condensation method, yielding the geoid. Both methods were used with the EGM96 geopotential model as reference, and results are compared to precise GPS levelling networks in Scandinavia, especially an accurate GPS data set from the very rugged Sognefjord region, where the topography was represented by either a detailed (100 m) or a coarse (1000 m) digital terrain model. The inclusion of bathymetry in the terrain model was also investigated. Even if two different methods were used, they produced almost identical results at the 5 cm level in the mountains, but small systematic differences exist. Results show that it is important in practice to compare the right types of geoid (classical geoid or quasigeoid), differences in residuals are significant.

QGF98, A NEW SOLUTION FOR THE GRAVIMETRIC QUASI-GEOID IN FRANCE.

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Efforts are continued for some years in order to improve high resolution geoid determination in France. A new solution is presented, based on the new global field model EGM96 and taking advantage of a careful scrutiny of the gravity data set. The new solution is compared to a GPS levelled network.

COMPARISON AND COMBINATION OF A GRAVIMETRIC GEOID WITH A LEVELLED GPS DATASET BY STATISTICAL ANALYSIS.

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For GPS levelling applications, it is convenient to express the height reference surface in some suitable geodetic reference system. This can be obtained through a set of levelled GPS points. Unfortunately, available data are sparse, and it become now usual to interpolate the height reference surface issued from GPS and levelling, using a gravimetric geoid. Both surfaces do not coincide exactly with each other. At this point, one must compare two realization of the geoid, detect outliers, retrieve (if possible) the causes of the discrepancies and finally combine the two kind of data. The paper presents some practical solutions to these problems.

AN ESTIMATION OF SARDINIA ISLAND GEOID BY ANALYSIS OF GPS/LEVELING DATA

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The National leveling net in Sardinia island is formed by an outer perimetrical ring and two lines which cross it from East to West and from North to South.
In late years two GPS surveys were performed in the island thanks to different Bodies and for different purposes; the vertexes of both the networks were connected to the benchmarks in order to experimentally determine geoidal undulation.
Nearly thirty benchmarks belonging to the National net were connected to as many vertexes suitable for GPS measurements by means of spirit-leveling; these vertexes were purposely materialized on the ground. In the last five years three GPS measurement campaigns were performed on this network.
Another large GPS network which is located in the island is a chain network running along the whole coast with the aim to frame numerical cartography of State-owned band at large scale. For this network the altimetrical link with more than forty benchmarks of National net was performed too.
Both the GPS networks are connected to Cagliari permanent station.
Either the ellipsoidal height in WGS84 system or orthometrical height of the vertexes belonging to the networks are therefore known with high precision. For them it was therefore possible to calculate geoidal undulation value in correspondence of the vertexes and therefore to estimate a local geoid.
The experimental values of undulation were compared with those predicted by theoretical model such as the global model EGM96 or the ITALGEO95 one, especially good for Italian country.
In this paper some results of performed analysis and comparison among the undulation values coming from different observations are presented.

VARIATIONAL METHODS IN GEOID DETERMINATION AND FUNCTION BASES

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The purpose of this paper is to discuss a variational method for the solution of geodetic boundary value problems and to give an interpretation of this method in terms of function bases. The choice of a boundary value problem relevant to the determination of the disturbing potential is approached first since it seems that it may be useful to give a fresh reasoning in this field. Then coefficients of a stiffness matrix are constructed for some particular function bases and also possibilities of orthogonalization are inferred. A great attention is give to the computation of integrals representing the right side of the respective system of linear equations. A particular emphasis is give to localization properties. Finally, the stability of the system is examined by means of a functional-analytic estimate.

LOCAL GEOID DETERMINATION BY WAVELET-VAGUELETTE DECOMPOSITION

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Compared to FFT the wavelet representation of a local geoid has some advantages

- The transformation into the wavelet domain is faster than the transformation into the Fourier domain.
- Wavelets provide the possibility of data compression and denoising.

Unfortunately, wavelets are in general not eigenfunctions of geodetic integral operators. Hence, the resulting system of linear equations is, in contrast to the Fourier case, not diagonal.
The idea of the wavelet-vaguelette technique is to use different systems of orthogonal functions for the data analysis and the solution synthesis. For the planar approximation of the Stokes integral a wavelet-vaguelette decomposition is to be presented.

THE COMPLETION OF THE NATIONWIDE GPS-GRAVIMETRIC GEOID SOLUTION FOR HUNGARY

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The establishment of the Hungarian National GPS Network (OGPSH) had been completed in 1997. It is settled on the traditional horizontal network sites. The OGPSH network consists more than 1100 GPS points, but less than 30% of the sites have levelled heights. Our task was to supply the remaining points with cm-accuracy heights above the geoid. For this purpose a technique was developped using the GPS data and the geoid information available. A specialized geoid solution, covering the whole contry was computed and used for supporting the GPS-heighting procedure. The GPS-gravimetric geoid makes the GPS-heighting very simple and efficient. The accuracy of the technique was extensively tested and proved to be accurate better than ±3 cm even in the worst circumstances. The improved technique is planned to use in the 3rd order levelling network

Studies on the Altimetry-Gravimetry Problems for Geoid Determination

For two decades, the altimetry-gravimetry problems are discussed in geodesy. They arise because the data situations on land and sea are different with respect to type and accuracy. For precise geoid determination in coastal regions, we have to take these facts into account. The theoretical framework of the altimetry gravimetry problems is the mixed boundary value problem for the Laplace equation. Its mathematical solution exhibits some irregular features along the coastlines, which will be found also in the computed geoid. Up to now, the recommended procedure in geodesy is to use overlapping data sets, if available. Then we arrive at a partly overdetermined mixed boundary value problem, which has not yet been treated theoretically. On the other hand, we can also design procedures, which take into account these features. In our studies, we work with two experimental designs: the Earth's equatorial plane, where the potential is assumed to behave according to the 2D Laplace equation, and the axisymmetric Earth model, which is frequently used in geophysics. We solve the experimental problems with various standard and alternative techniques. This serves as a guideline for the choice of the technique to be applied. It also reveals some unsolved problems.

A COMPARISON OF CLASSICAL AND SJÖBERG'S APPROACHES TO TERRAIN CORRECTIONS IN GRAVIMETRIC GEOID DETERMINATION

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This paper investigates three approaches for compting the terrain effects in the gravimetric geoid determination. First method is the classical approach which is documented by Moritz. The second classical approach is developed by Vaníček and Kleusberg . Direct terrain effect in Moritz appraoch has been reduced to a surface with constant elevation, i.e., geoid whereas in Vaníček and Kleusberg approach this effect has been reduced to a varying surface depending on topography but in a different way. A different way has been used to compute terrain effects in Sjöberg's approach. This third method is based on spherical harmonic theorems. Direct terrain effect in Sjöberg's approach has been derived at the topographical surface of the earth. Numerical investigations has been carried out in two regions A and B in Sweden. The region A has a smooth topography where region B has a rugged topography. Comparison of these there approaches show large differences in test region B. The range of the Vaníček and Kleusberg direct terrain correction (-66 to 21 mGal) was substantially larger than in the Moritz (0 to 17 mGal) and Sjöberg's (-540 to 250 μ Gal) approaches. The range of the indirect effect in Moritz (or Vaníček and Kleusberg) approach was -4 to 8 cm where it was 4 to 6 cm for the sjöberg's approach.

MODELING OF LONG WAVELENGTH SYSTEMATIC ERRORS IN SURFACE GRAVIMETRIC DATA

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Long wavelength systematic errors in (near) global gravity anomaly data bases have been identified as a major limitation of these data for several years now. The specific origin of these systematic errors is not clearly understood, although several possible causes have been identified [*Heck*, 1990]. To minimize their effects, down weighting (sometimes rather arbitrary) of surface gravimetry, and elimination of its very long wavelength contribution is employed in current global geopotential solutions. This investigation attempts to separate the long wavelength systematic errors (in the form of low degree surface spherical harmonic models), from the valid gravitational signal present in the data. This is done in a combination solution environment where satellite tracking information and surface gravimetry are simultaneously adjusted.

The presentation will describe the technique employed and the initial results obtained. The possible incorporation of altimetric information into the solution will also be addressed.

A NEW GLOBAL TOPOGRAPHIC-ISOSTATIC MODEL

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This paper proposes a global topographic-isostatic model. It comes from a completely new idea — the geoid undulation is the responses of an elastic earth to the topographic mass load. We assume the topography as a condensed surface mass load, and we derive expressions for calculating the vertical displacement, potential, gravity and equipotential surface changes, based the load theory proposed in Sun and Sjöberg (1996). We also discuss the mass conservation problem and some calculating techniques. We define and discuss the geoid factor $\Lambda = 1 + k'_n(a) + h'_n(a)$ which is composed of three parts: loading potential, surface displacement and mass redistribution. In practical calculations we adopt the Getech's Global Digital Terrain Model (DTM5), the load Love numbers and Green's functions obtained from the 1066A earth model, and the combined European model GFZ93a. We mainly calculate and discuss the vertical displacements and equipotential surface changes for four depths: deformed and undeformed surfaces, 36 km and the core-mantle boundary. The total geoid undulations at the earth's surface caused by the topographic mass load vary between -262 and $+145$ m, which are basically close to the observed geoid undulations in magnitude and in distribution pattern. Results show a high correlation between the deformations and the topographic load, but a strong negative correlation between the modeled and observed geoid undulations.

RECENT GEOID COMPUTATIONS FOR THE HELLENIC AREA

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New geoid computations for the Hellenic area are carried out using (a) gravity anomalies for the land area available from old and new data bases, and gravity data for the sea area derived from altimetry and a recent digitization of sea gravity maps, and (b) a $1km \times 1km$ topography/bathymetry digital model. The EGM96 geopotential model is used as the reference field. In order to assess the accuracy of the computed geoid heights in the continental area comparisons were carried out with GPS/levelling heights. In the sea area the geoid heights were compared with sea surface heights of the recent and most accurate TOPEX altimetric mission.

AN ACCURACY ESTIMATION OF GRAVIMETRIC TERRAIN CORRECTIONS

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The gravimetric terrain correction plays an important role in the refinement, smoothing and prediction of the Earth's gravity field for applications in geodesy and geophysics. However, the accuracy of the computed terrain correction depends upon the accuracy of the digital terrain model (DEM), the 3-D position of the point of interest, and the assumption of a uniform topographic density. This paper provides a theoretical derivation and a numerical evaluation of the accuracy of the terrain correction. In the topographically rough areas of Australia (eg. Tasmania), where the mean terrain correction is greater than 1mGal, the errors in the height and planar position of the DEM dominate the terrain correction computation. Conversely, in the topographically flat areas of Western Australia, where the mean terrain correction is less than 0.5mGal, the accuracy of the height of the point of interest becomes more critical. It is also shown that errors in the planar position of the point of interest and the assumption of a uniform topographic density have a lesser effect. The formulae derived here can be also used to decide upon the spatial resolution of the DEM used to compute the gravimetric terrain correction.

ON THE DETERMINATION OF A NEW AUSTRALIAN GEOID

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A new, high precision, high accuracy gravimetric geoid of Australia has been produced using most updated data, theory and methodology. The absolute accuracy of the geoid is higher than 33cm when compared with the Australian National GPS/levelling networks. The relative precision of the new geoid is better than 10cm for average baseline lengths 4km~40km and 20cm for average baseline length 150km when compared with three local GPS/levelling networks. In addition, a number of theoretical and practical problems such as: data reduction, selection and verification of the optimal geopotential model and its representative errors, special features of the Australian gravity field and optimal gridding of the gravity anomalies, theory and implementation of the FFT technique for geoid computation and terrain reduction including edge effect, zero padding, spectral leakage and aliasing effects, have been also investigated. The satellite altimetric gravity data have also been evaluated and combined with marine gravity data to improve density and coverage of the gravity data, and the quality of the geoid as well, particularly in offshore areas. It is demonstrated that a proper inclusion of satellite altimetric gravity data can give RMS improvement of the gravimetric geoid up to 10cm.

Finally, the methodologies developed in this presentation is pertinent to other part of the world for a gravimetric geoid determination over a large area.

G12 Effects of the atmosphere, ocean and core on nutation, polar motion and length of day (co-sponsored by SE)

Convener: Schuh, H.
Co-Convener: Salstein, D.A.

01 Effects of the atmosphere

Convener: Gegout, P.

Sponsorship:

INFLUENCE OF THE HYDROLOGICAL CYCLE ON THE SEASONAL CYCLE OF EARTH ROTATION AND GRAVITATIONAL PARAMETERS

R. Abarca del Rio (GRGS/CNES. CNRS/UMR 5566. 18 av Edouard Belin. Toulouse. France)

We present an analysis of the Hydrological cycle variations through 1979 to 1995. and the associated variations on Earth Rotation and Gravitational Parameters.
The hydrological cycle is obtained from both the reanalyses of NCEP from 1979 through 1995 as from mesurements of snow depth (SMMR from 1979 to 1988 and SMMI from 1989 to 1995). We present as well results issued from the ISLSCP initiative (ECMWF data for 1987 and 1988) and those from the climatologies of the hydrological cycle of Willmott et al. (1984) and that of the snow depth of Foster et al. (1995). The results concerning the annual cycle will be compared with those obtained from an special run of the UGAMP model (Dong et al. 1994) and criticized in view of actual knowledge of the hydrological cycle and particularly that of the global Earth groundwater variability. Finally seasonal evolution of the snow seasonal cycle over 1979-1995 will be particularly emphasised in view of the results of Abarca del Rio (1997) (Ph.d) which tend to prove that the accumulated snow plays the most important role on the hydrological cycle on the earth's polar motion seasonal cycle. and is of special relevance for the X1 term.

INTERANNUAL AND DECADAL TIME SCALES IN THE EARTH ROTATION (LOD), ATMOSPHERIC MOUNTAIN STRESS TORQUES (AMST) AND THE ATMOSPHERIC ANGULAR MOMENTUM (AAM)

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The objective of this study is to compare the variability of the Earth rotation (LOD). with the Atmospheric Mountain Stress Torques (AMST) and the Atmospheric Angular Momentum (AAM).
Interannual LOD variations. excluding a 5-6 year period detected by Vondrak (1977) which is not excited by the atmosphere (Djurovic and Paquet. 1996. Abarca del Rio. 1997) are dominated by the ENSO phenomena and the Quasi Biennial Oscillation of stratospheric winds (Chao. 1989). At decadal time scales we have shown that the variability of the Angular Momentum of the zonal winds can explain the 10-11 yr period of LOD. whereas a 14.2 yr period closely linked to the SOI decadal variability may be excited by the variability of the oceans (Abarca del Rio. Gambis and Salstein. 1997). Although the theory assumes that the variabilities of both the Angular Momentum and the Mountain stress are closely related (Wahr and Oort. 1983). the analysis of the variability of the mountain stress and comparison with Angular Momentum has for instance only been performed at high frequencies (Salstein. 1997) and at interannual time scales (Bos and Gambis. 1996).
In this study we will present an analysis of the relationship at interannual and decadal time scales in both series (AMST and AAM). The low frequencies signature present in both series are investigated together with the principal patterns of the regional variability which are associated.

ATMOSPHERIC AND OCEANIC EFFECTS ON NUTATION OF THE EARTH

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Nearly diurnal variations in the distribution of the atmospheric and oceanic masses and in the pattern of winds and ocean currents, change the angular momentum of these two fluid media which, in turn, induce nutational motion of the solid Earth through the conservation of the total angular momentum. This motion is small in comparison to the lunisolar effect, nevertheless is significantly larger than the current accuracy of observations, therefore should be taken into account in the new non-rigid Earth nutation theory. An estimation of the atmospheric and oceanic influences on nutation and comparison with the VLBI measurements of the nutation angles, can also provide constraints on different geophysical parameters related both to the internal constitution of the Earth and to the global circulation models of its outer fluid layers. In this paper we review recent advances in modeling atmospheric and oceanic effects on nutation. We also report our own estimates of the atmospheric contributions to nutation, using new 29-year homogeneous time series of 6-hourly atmospheric angular momentum determinations.

ATMOSPHERIC ANGULAR MOMENTUM VARIABILITY AND ASSOCIATED ATMOSPHERIC PATTERNS ON DIFFERENT TIMESCALES SIMULATED WITH THE ECHAM3 T21 GCM

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The atmospheric angular momentum (AAM) underlies fluctuations of different periods. These variations are highly correlated to the changes of the earth rotation at least on timescales of hours up to a couple of years. The simulated AAM budget of the ECHAM3 T21 global circulation model (GCM) is analysed. Five simulations with different initial states were forced by observed monthly means of sea surface temperature and global ice coverage (GISST-dataset from Hadley center, Bracknell) for the corresponding period from 1949 until 1994. The simulated relative AAM timeseries shows significant variability on different timescales particularly on the interannual timescale and correlates very well with the change of the length of day (LOD) observed by VLBI measurements. The mechanisms of angular momentum transfer between atmosphere, ocean and solid earth are investigated. Some significant patterns of the atmospheric circulation associated with anomalies of the contributors of the AAM budget derived by multivariate statistical tests will be shown. On the interannual timescale these patterns corresponds to well known patterns of the El Niño Southern Oscillation (ENSO).

ANGULAR MOMENTUM EXCHANGES BETWEEN THE EARTH AND THE HYDROSPHERE AND CONSEQUENT LENGTH OF DAY VARIATIONS

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Seasonal and interannual fluctuations of the solid Earth's angular momentum are mostly due to angular momentum exchanges between the solid Earth and the hydrosphere. Inside the hydrosphere, angular momentum is transported by winds in the atmosphere, currents in the oceans, and water masses redistributions inside the atmosphere, the ocean and water storage at the continents surface. Through pressure, gravitational and friction torques, angular momentum is exchanged between the hydrosphere and the solid Earth. We have evaluated the global hydrospheric angular momemtum budget from atmospheric global circulation model (NCEP/NCAR reanalysis), oceanic circulation model forced by atmospheric winds (Miami Isopycnic Coordinates Ocean Model), oceans forced by atmospheric pressure (Topex/Poseidon), snow and soil moisture (NCEP/NCAR reanalysis), glaciers, ice caps, and hydrological reservoirs. Comparison between observed and modeled variations of the length of day provide insights of the involved interaction processes.

SEASONAL LENGTH-OF-DAY CHANGES AND AXIAL ATMOSPHERIC-ANGULAR-MOMENTUM OSCILLATIONS IN THEIR TEMPORAL VARIABILITY

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Recently, effective Atmospheric-Angular-Momentum functions (AAM) as calculated from NCEP (formerly NMC) and NCAR reanalyses have become available from 1968 to 1997. Concerning the wind terms, the top level in the atmosphere used here is 10 hPa. Compared with earlier NMC model versions which incorporate wind fields up to 100 hPa since 1976 and up to 50 hPa since 1981, the reanalyses have produced improved data series over a time longer as before. The axial AAM component χ_3 is associated with changes in the Length-Of-Day (LOD). Motivated by better quality and continuity of the series AAM (NCEP) REANALYSIS, the problem of the seasonal imbalances in the solid Earth-atmosphere axial angular momentum budget is re-examined. To assess better the estimates of the annual and semiannual oscillations in LOD and AAM and of the residual oscillations derived as difference series between LOD and AAM, the series of LOD data from three analysis centers (IERS, GFZ, JPL) and of AAM data in terms of $\chi_3(W)$, $\chi_3(P)$ and $\chi_3(P+IB)$ from four meteorological centers (NCEP, JMA, ECMWF and UKMO) are used. The main analysis steps were removing gaps, filtering out the seasonal oscillations, calculating optimal estimates of the parameters of the oscillations and calculating the difference series between the LOD and AAM systems as well as the residuals in the axial angular momentum budget in the LOD-AAM-systems. The results derived in the different systems show to which extent the variations reflect systematic differences and significant signals, respectively, which is important for future activities in this field.

ATMOSPHERIC EXCITATION OF PROGRADE DIURNAL POLAR MOTION

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Changes in the atmospheric angular momentum have been demonstrated to excite a large part of the seasonal polar motion as well as to produce a measurable effect on nutation. In this paper we focus on the equatorial angular momentum of the atmosphere in the range of prograde nearly-diurnal frequencies, and its corresponding influence on polar motion. We use the 29-year atmospheric angular momentum series obtained recently from NCEP/NCAR reanalysis to estimate the atmospherically driven prograde diurnal polar motion constituents. On the other hand, the sub-diurnal polar motion observations are used for comparison with the latter estimates, after accounting for the ocean tide effects as well as for the effect of Earth's triaxiality. Applicability of the inverted barometer correction in this frequency range is studied. One more question which is addressed here is the variability, or broad band nature, of the prograde nearly-diurnal polar motion caused either by atmospheric or oceanic effects or by a combined atmosphere/ocean influence.

TROPICAL AND EXTRATROPICAL EXCITATION OF SUBSEASONAL VARIATIONS IN THE EARTH'S ROTATION RATE

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On subseasonal time scales, the largest component of axial atmospheric angular momentum (AAM) variation is associated with the tropical Madden-Julian (MJ) oscillation. This phenomenon takes the form of a convectively driven, eastward-propagating disturbance in the Eastern hemisphere, with its fastest growth rate over the western Indian Ocean. Its preferred period is about 50 days, which may reflect the transit time for the disturbance to propagate completely around the equator. Subseasonal variability also arises in the extratropics, from the interaction of jet streams with the large-scale topography. In analytical and equivalent-barotropic models, this phenomenon takes the form of a standing, wavenumber-two oscillation in the Northern Hemisphere (NH) extratropics, which generates alternating westerly and easterly mountain torques through a tilted-trough vacillation mechanism. We have found a similar oscillation in a version of the UCLA General Circulation Model (GCM) which, like most current GCMs, lacks a robust simulation of the MJ oscillation. Teleconnections from the model's extratropical oscillation extend into the tropics, and in particular appear to excite an incipient MJ oscillation over the model's western Indian Ocean. We will consider the possible role of topographically induced extratropical variability as a source for the excitation of oscillations in tropical global AAM, and hence in the Earth's rotation rate, on these time scales.

WAVELET ANALYSIS OF POLAR MOTION AND ANGULAR MOMENTUM TIME SERIES

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Time series of polar motion and of angular momentum variations from 1980 to 1996 have been analyzed by means of wavelet transformations.
From the polar motion data the Chandler wobble was reduced, first. The angular momentum data consist of AAM (atmospheric angular momentum), OAM (oceanic angular momentum) and OTAM (oceanic tidal angular momentum). The AAM data published by the IERS are used. The OAM data and OTAM data were obtained by numerical integration of four years of the Topex/Poseidon sea surface height anomalies and the CSR3.0 ocean tide model respectively.

ATMOSPHERIC REGIONAL SIGNALS IN EXCITATIONS OF POLAR MOTION - ANALYSIS OVER A 40 YEAR PERIOD

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The atmospheric influence on polar motion occurs by an exchange of angular momentum between earth and atmosphere in the equatorial plane. This atmospheric component is formalized by the so - called effective atmospheric angular momentum (EAAM) excitation function. A better understanding of polar motion - atmosphere relationships needs an analysis of interactions between regional atmospheric variations and both polar motion and global atmospheric excitation. It was shown earlier that part of the Eurasian region is particularly important for exciting high frequency polar motion. The previous investigations were based on about 30 years period. Here the EAAM functions are computed from all 40 years of NCEP/NCAR Reanalyses both globally and in selected geographic sectors. We use the full period 1958-1997 to analyze regional and global atmospheric excitation functions to assess how different regions contribute to the angular momentum functions of the global atmosphere. Also, the time variability of oscillations in selected regions and their relationship to interannual signals such as ENSO are analyzed. In addition, we investigate regional contributions of atmospheric angular momentum to excitations of polar motion on several important frequencies (from several days to semi-annual scales).

INTERANNUAL SIGNALS IN ATMOSPHERIC ANGULAR MOMENTUM FROM A 40-YEAR REANALYSIS

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The recent release of reanalyzed surface and upper-air fields by the U.S. NCEP/NCAR allows interannual signatures of atmospheric angular momentum (AAM) to be determined since 1958, a lengthier period than was available heretofore. Based on the zonal wind structure through the troposphere and stratosphere, integrated AAM varies on a range of time scales from daily to decadal. Interannual and shorter signals are closely coupled to those in length-of-day, whereas subtracting AAM values from l.o.d series allows the remaining, mostly decadal, signals to be related to fluctuations within the Earth. The most prominent interannual signal is tied to the El Niño/Southern Oscillation, a phenomenon manifested by sea surface temperature and air mass fluctuations across the tropical Pacific, with dynamic consequences for tropospheric winds in other latitudes. The major 1982-83 ENSO warm event, for example, resulted in a record value of AAM in January 1983; strong AAM anomalies related to ENSO are evident throughout the record, most recently in conjunction with the event that started in the first half of 1997. Stratospheric series of axial AAM include a quasi-biennial signature, caused by the reversal of tropical zonal wind anomalies. Some of these features can be identified in models of the atmosphere that are driven by observed boundary conditions alone, providing a measure of confidence in using such models for climate purposes. We examine other aspects of interannual signals in momentum including characteristic time scales and contributions from various regions.

INTRASEASONAL OSCILLATIONS IN GLOBAL ATMOSPHERIC ANGULAR MOMENTUM

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Building on studies of 30-70 day global atmospheric angular momentum (AAM) oscillations, sub-monthly variations of AAM are investigated. Sub-monthly AAM accounts for about 6% of the total variance of AAM anomalies. NCEP/NCAR reanalysis data are regressed onto a variety of high-pass filtered, global indices using sixteen November-March, 150-day segments. The results indicate that there are three modes of sub-monthly variation. Two are oscillatory and the third appears to be stochastically forced. The two oscillatory modes are dominated by the mountain torque but also have a substantial frictional torque. One of these is characterized by a zonal mean mass exchange between the tropics and high northern latitudes (the ME mode) and the other by zonal mean momentum changes in the subtropics (the MR mode). The mountain torque over Asia dominates the ME mode while the MR mode is forced primarily by the North American mountain torque. The two modes are uncorrelated and together produce variations in total AAM and Length-of-Day which are focused in the 15-30 day time band. The MR mode dominates the total AAM having about three times the variance of the ME mode. The third mode, which is obtained by regressing onto the global mountain torque, produces a majority of the sub-monthly global AAM tendency but only a quarter of the global AAM variance itself. It is produced by synoptic-scale wavetrains, which disperse from oceanic storm tracks and impinge on the major topographic barriers. The mode?s global mountain torque is about 12x greater than the frictional torque and consists of a random mixture of contributions from the primary mountainous regions. The three-dimensional structure and synoptic evolution associated with the three modes will be presented as well as evidence for dynamical and synoptic links between the MR mode and 30-70 day AAM fluctuations.

G12 Effects of the atmosphere, ocean and core on nutation, polar motion and length of day (co-sponsored by SE)

Convener: Schuh, H.
Co-Convener: Salstein, D.A.

02 Effects of the ocean

Convener: Sündermann, J.

The Role of Ocean Variability in the Earth's Rotation: A Geodetic Application for the Parallel Ocean Climate Model

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This research examines the role of the oceans in the temporal variability in the Earth's rotation as predicted by the Parallel Ocean Climate Model. This free-surface high resolution ocean model allows the estimation of variability in the Stokes coefficients resulting from mass redistribution forced by wind fields and heat fluxes predicted from an operation meteorological center. First, the ocean model's angular momentum is compared to the angular momentum determined from geodetic measurements. I will show that the oceans account for a significant part of the discrepancies in the angular momentum budget for the Earth and its fluid envelopes. Finally, this study briefly addresses the importance of mountain and frictional torques in the transfer of angular momentum to the solid Earth. Overall, this research indicates the important role the ocean plays in balancing the planetary angular momentum budget.

EFFECT OF OCEAN LOADING ON THE DETERMINATION OF EARTH ORIENTATION PARAMET ERS

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Space geodetic techniques (e.g. VLBI, GPS) observe Earth orientation parameters (EOP) with high accuracy. The analysis of the space geodetic measurements requires a precise modelling of all Earth deformation effects in order to determine the EOPs accurately. Space geodetic networks used for Earth orientation studies include stations with large vertical and horizontal ocean loading effects, e.g. the station Fortaleza at the Atlantic coast of Brazil. In these networks, ocean loading effects have a rigid rotation mode and therefore can affect the determination of EOPs.
The effect of ocean loading from different ocean loading models on the determination of EOPs from geodetic VLBI networks will be discussed.

THE HYDROSPHERE'S IMPACT ON EARTH ROTATION

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The ocean circulation is not only driven by thermal-haline forces. The interchange of angular momentum between the hydrosphere and the solid Earth is another fundamental factor. This can be demonstrated for the ENSO-events, for the last centuries' instrumental data, for decadal-to-century changes during the Holocene, for the high-amplitude climatic-eustatic changes some 13-10 ka ago, and for the main glacial/inter-glacial cycles. The oceans have a remarkable heat-storing capacity. Any change in the ditribution of the water masses will have strong effects on the global climatic temperature distribution. The oceans contain huges masses of water of a reasonably high density that are constantly circulating both horizontally and vertically over the globe. Any irregilarity in this circulation leads to a redistribution in total mass which affects the sea level and has to be compensated by an interchange of angular momentum between the hydrosphere and the solid Earth. This means that we in the recorded past changes in climate and in sea level can obtain information about possible past changes in ocean circulation, too. And this is exactly what our paleo-records seem to indicate.

COMBINED OCEANIC AND ATMOSPHERIC EXCITATION OF POLAR MOTION FOR THE PERIOD 1993 -1995

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We use both atmospheric and oceanic effective angular momentum functions to focus on short period oscillations of polar motion. The relevant equatorial excitation functions, chi1 and chi2, are calculated over a three-year period. For the atmosphere, chi1 and chi2 are computed from NCEP/NCAR Reanalyses data. To estimate similar excitation functions for the ocean, we utilize output from a simple constant-density numerical ocean model forced by NCEP/NCAR winds stresses and pressures. Combined oceanic and atmospheric excitation compares better with geodetic series than atmospheric excitation alone. When mass-related oceanic signals are added to those of the atmosphere, correlations between observed polar motion and the geophysical excitation series increase from 0.54 to 0.72 and from 0.75 to 0.8 for χ_1 and χ_2, respectively. Coherence and phase analyses indicate that the oceans contribute coherent power to short period polar motion excitation in the spectral range from several to 150 days.

UNDERSTANDING THE OCEAN'S ROLE ON THE VARIABLE EARTH ROTATION

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Recent developments in modeling and data gathering have led to the ability to estimate the variable ocean circulation and mass fields on a global scale. These fields in turn permit the determination of the oceanic angular momentum (OAM) about the polar and equatorial axes. The procedures to estimate OAM are reviewed with a focus on the diagnosis of the mass field and ways of dealing with the unrealistic volume-conserving formulation of most current ocean models. Recent calculations of OAM are then examined to quantify the relative contribution of currents and mass field fluctuations to OAM signals and to highlight the role of the oceans in the context of the planet's angular momentum. Results to be discussed include the mounting new evidence for the importance of oceanic excitation in explaining observed polar motion, on seasonal and shorter periods. In the case of length-of-day, the role of the ocean as a conveyor of angular momentum signals between the atmosphere and solid Earth is revisited, with regard to the possible short lags introduced in the coupled system by the oceanic transmission process.

ON THE CONSIDERATION OF OCEAN TIDES IN AN OGCM AND IMPLICATIONS ON EARTH'S ROTATION

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Numerical World Ocean models can still be divided into (baroclinic) OGCM's forced with wind stress, air temperature fields and freshwater fluxes and (barotropic) tidal models. Until now there is no numerical model that is capable of describing the world ocean's instantaneous real dynamics by a simultaneous calculation of the two components of motion.
To investigate the significance of non linear interactions of the world ocean's general circulation and tides an OGCM is additionally forced with the astronomical tidal potential. This extended model is especially designed to examine variations of the world ocean's angular momentum on time scales from hours to decades resulting from real-time forcing (NCEP, ECHAM3-simulations). Further, the results give hints on the accuracy of the separation of numerical models into pure OGCM's and tidal models, i.e. of the linear superimposition of the two contributions to the ocean's motion field resulting from atmospheric and astronomical forcing.
After a short survey of the model's structure first results with respect to angular momentum, tensor of inertia, and the Earth's centre of mass will be presented.

G12 Effects of the atmosphere, ocean and core on nutation, polar motion and length of day (co-sponsored by SE)

Convener: Schuh, H.
Co-Convener: Salstein, D.A.

03 Effects of the core

Convener: Dehant, V.

ABOUT THE INFLUENCE OF THE CORE ON NUTATIONS: A BEGINNING.

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It is presently possible to compare very precisely the observed nutation as derived from Very Long Baseline Interferometry (VLBI) with the computed nutation for a model of a non-rigid Earth initially in a non-hydrostatic equilibrium with an elastic inner core, a liquid core and an inelastic mantle.
The comparison shows that there are still differences at the level of some tenths of milliarcsecond, far above the internal precision of VLBI data. As seen from some results found in the literature and from some simulations, these differences are due to the core. This is the reason why we have reviewed the existing core modeling. The paper shows these results and takes conclusions about the direction one should take to compute the core effects. We also plan to show the order of magnitude of the effects.

GEOPHYSICAL PARAMETERS DERIVED FROM THE HAMILTONIAN NON–RIGID EARTH THEORY

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In the last years the authors have been working in an analytical non–rigid Earth rotation theory, following the Hamiltonian approach. At the present stage of development, the study of a simplified two–layer model (elastic mantle and liquid core) with dissipation is finished, and the solution of the three layer case has been partially fulfilled and is in progress.
The nutation series depend analytically on some geophysical parameters, that can be computed from a selected Earth model (1066A, PREM, etc.) or even adjusted by comparison with observed nutation series. The last option gives rise to an error < 0.1 mas in all frequencies. In this communication we put the **** on the values of the geophysical parameters recovered by such adjustment procedure, especially the dynamical ellipticities of the solid Earth and its three components.
This kind of comparison among values derived from nutation observation or rheological Earth models is interesting to check both astronomical and geophysical theories. The main feature of our parameters is that the procedure of derivation is completely self–consistent, that is, all the components of the nutation amplitudes are computed with the same values of the parameters, what is not possible in the usual approach (rigid theory + transfer function).

ABOUT THE INFLUENCE OF A POSSIBLE RELATIVE ROTATION OF THE EARTH'S INNER CORE ON THE POLAR MOTION, THE GEOMAGNETIC FIELD AND THE GRAVITY FIELD

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Provided that the figure axis of the inner core coincides with the dipole axis of the geomagnetic field, the relative rotation of the oblate inner core with respect to the outer core and the mantle can be determined. Because of the density difference between the inner and outer core, this motion is accompanied by a mass redistribution causing long term variations of polar motion. Assuming standard density models, it is found that variations of polar motion caused by inner core rotation are similar to those derived from pole coordinates. To examine the assumption on the orientation of the figure axis, its angle with respect to the dipole axis is investigated. The dynamo process is simulated by a prescribed electric current system within the outer core. Coincidence of both axes can be reached if the modul of the angular velocity of the inner core is sufficiently high and if the current system is concentrated within a thin sheet near the outer core-inner core boundary. Calculatio! ns of the gravity potential show that the rotation of the inner core may cause gravity changes which can be detected by modern satellite methods if the corresponding data series are sufficiently long.

AXIAL TORQUES ACTING BETWEEN CORE AND MANTLE

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Torques acting between core and mantle are discussed. On very long timescales (10^3 years and more), core and mantle are tightly coupled by viscous and magnetic forces. However, viscous and magnetic torques appear too weak to account for l.o.d. changes on decadal time scales. A new derivation of the electromagnetic torque, which does not rely on core velocity models, is presented. It allows to pinpoint magnetic field data that loosely constrains the value of this torque. Mantle conductance seems too small by two orders of magnitude for this torque to be significant. As a consequence, pressure forces acting on smooth bumps at the core-mantle boundary are probably responsible for decadal changes in l.o.d. We show that the topographic torque scales as the bump height h in contrast with theoretical calculations based on motions excited by the topography that yield $O(h^2)$ values. Finally we show that both gravitational and topographic torques can be interpreted as the consequence of distortions of the geostrophic contours and as such, they can hardly be distinguished.

EARTH ROTATION AND CORE MODELING: COUPLINGS OF THE MANTLE, OUTER CORE, AND INNER CORE

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Perturbations in the angular velocities and relative orientations of the mantle, fluid outer core, and solid inner core bring into play gravitational, pressure, electromagnetic, and other torques that couple the rotational motion of each region to those of the others. The eigenfrequencies of this coupled system and the strengths of the associated resonances in forced nutations are sensitive to the parameters of the torques. Prominent among these are the core mantle boundary (CMB) flattening, the magnetic field strength at the CMB and the electrical properties of the mantle layers immediately above, and the flattening of, and the magnetic field strength at, the inner core boundary (ICB). The effects of both the CMB and the ICB couplings could be surprisingly large with realistic values for the parameters. Independent estimation of CMB and ICB parameters is possible from nutation data since they affect different resonances and are manifested in different parts of the nutation spectrum. We shall present estimates (obtained using high-precision nutation amplitude estimates from 18 years of VLBI data) for the CMB flattening and the magnetic coupling parameters at both the boundaries, and discuss their implications.

WHEN ARE THE CORE AND MANTLE COUPLED?

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The angular momentum budget of the Earth has been studied across a broad range of timescales. For the axial component, the core is thought to be important on decadal timescales. Researchers have found a good agreement for this century between changes in the axial angular momentum of the core inferred geomagnetically and those inferred from geodetic observations of Earth rotation. On much shorter (annual and subannual) timescales, the atmospheric angular momentum (AAM) is very coherent with LOD. If there is core-mantle coupling on these timescales, the main effect would be to cause the core to respond to differential motion of the mantle forced by the atmosphere. We explain how this would cause a phase lead of LOD ahead of AAM. There is some observation evidence for such a phase difference: we discuss the implications, and the role of the oceans. If dynamic core-mantle coupling occurs at the core-mantle boundary (CMB), then coupling requires not only a mechanism to transmit momentum across the CMB but also a mechanism to transmit the momentum between the boundary region and the bulk of the core. Therefore, the internal dynamics of the core may play an important role. Core dynamics are frequency dependent and are also strongly influenced by the Earth's rotation. If axisymmetric inertial waves are important for axial core-mantle coupling, then non-axial coupling may be less efficient as these waves have no direct equatorial counterparts.

G12 Effects of the atmosphere, ocean and core on nutation, polar motion and length of day (co-sponsored by SE)

Convener: Schuh, H.
Co-Convener: Salstein, D.A.

04 Models, measurements and analysis of Earth rotation

Convener: Schuh, H.

WAVELET ANALYSIS OF THE POLAR MOTION

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Wavelet Analysis is applied to analyze the total polar motion. First, the wavelet transform is used to identify the components (prograde and retrograde) present in the data. This wavelet transform is subsequently used to filter and reconstruct each component. We show how the ridge of the wavelet transform may be used to localize and characterize rapid phasejumops in the data. On synthetic data we show how the characterstic parameters (duration, amplitude, position) may recovered from the wavelet transform ridge. This technique is applied to the polar motion data. We find that at most ten phasejumps are needed to explain the oscillations of the ridge function. It is found that all but one phasejumps have durations of less than 2 years and each of them is followed by a geomagnetic event within at most 3 years. Simple statistal test asses the corelation between both types of events. Simple physical models of the core-mantle coupling show that the observed phase jumps correspond to torques of about 10^{20} Nm.

ANGULAR MOMENTUM VARIATIONS IN THE GEOPHYSICAL FLUIDS

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Global-scale mass transport in geophysical fluids of the atmosphere-hydrosphere-solid Earth-core system gives rise to global, albeit slight, geodynamic variations, including those in angular momentum (AM), in gravitational field, and in geocenter location. Under the conservation of AM, any AM variation in the geophysical fluids is accompanied by a corresponding, but reverse variation in solid Earth's rotation. The latter, in both UT1/length-of-day (LOD) and polar motion/nutation, have been observed for years with increasing precision and temporal resolution by means of space geodetic techniques. Five major types of global geophysical fluid mass redistribution will be discussed: (1) Atmospheric AM (AAM) has been known to be the dominant cause for Earth rotation variations on time scales from a few days to several years. A number of weather centers and NASA's Data Assimilation Office provide computed AAM series. (2) Wind-driven Oceanic AM (OAM): Significant advances in OAM studies have been achieved recently, based on computations using a state-of-the-art ocean circulation models. Correlations have been found between such "predicted" OAM and the non-AAM Earth rotation variations. Equally important, oceanic altimeter measurements, such as those from the Topex/Poseidon (T/P) satellites when used in conjunction with ocean circulation models to separate out steric effects, will provide independent estimates of OAM. (3) Oceanic Tidal AM (OTAM) has been successfully computed based on various ocean-tide models and observations, particularly those derived from the T/P observations. Such OTAM estimates agree remarkably well with actual Earth rotation measurements (both long-term and high-frequency during intensive campaigns), paving the way for the study of high-frequency non-OTAM (such as seismic) effects. (4) Continental Hydrological AM (HAM): Hydrological variations include rain and snow precipitation, polar and mountain glaciers, polar ice sheets, underground water storage, and artificial reservoirs. Large uncertainties exist in the HAM estimates due to lack of global observations and modeling errors. (5) New studies using geodynamo models can shed light on the fluid core flow and hence the Core AM (CAM)'s magnitude and time scales, the core-mantle coupling mechanisms, and motion of the solid inner core. Seismological evidences, nutations, and decadal LOD variations provide observational constraints.

Signatures of ENSO in LOD

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VLBI is one of the most important techniques for measuring Earth orientation parameters (EOP), and is unique in its ability to make high accuracy measurements of UT1. These measurements of EOP give constraints on geophysical models of the solid-Earth, atmosphere and oceans. Changes in EOP are due either to external torques from gravitational forces, or to the exchange of angular momemtum between the Earth, atmosphere and oceans. The effect of the external torques is strictly harmonic and nature, and is therefore easy to remove. We analyze an EOP time series derived from VLBI measurements with the goal of identifying large scale ocean-atmosphere patterns in the VLBI data. Previous work by other investigators demonstrated a high degree of coherence between atmospheric angular momemtum (AAM) and EOP. We study the residual signal obtained by subtracting the AAM contribution from EOP. Changes in this series are due predominantly to changes in the oceanic angular momentum. We analyze this series in several ways, including Fourier analysis, windowed Fourier analysis, band-pass filtering, and wavelet analysis. We show that the signature of previous el Nino-Southern Oscillation (ENSO) events is easily discernible in the length-of-day (LOD) data. Most of these analysis techniques have the drawback that the data must contain all or most of an ENSO event for it to be discernible. Hence they are good at detecting the ENSO event, but not at prediction or real-time detection. We therefore investigate various schemes for filtering the EOP data to provide early detection of ENSO events. We find that removing the long term secular variation in LOD enhances the signature of the ENSO. For most of 1997 the detrended LOD was larger than normal. The current 1997 ENSO continues to develop in interesting and unexpected ways. We plan to update our analysis of ENSO and LOD with all data available prior to the EGS meeting.

INFLUENCE OF GLOBAL MASS DISPLACEMENTS ON EARTH ROTATION

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Geophysical processes produce global redistributions of masses. We distinguish between direct and indirect influences of these mass displacements on the rotation vector of the Earth. Direct effects result from the changes of the tensor of inertia due to the mass displacements and from mass motions relative to the terrestrial system. Mass redistributions influence also indirectly the Earth rotation by changing the moments of inertia by load deformations. Deformations due to oceanic and atmospheric loading are well-known effects. The influences of small surface deformations caused by snow and ice cover or groundwater level variations are also looked at. Our investigations are based on the Euler-Liouville differential equations. Higher order terms have been analysed in order to verify the commonly used linearization. Simulations of snow cover and water level variations are presented to estimate the magnitude of the resulting perturbations in Earth rotation. The influence of the motion terms of angular momentum is compared with that of the matter terms. This is of particular interest in the case of slow mass displacements of water, which is evaporated from the oceans and temporally deposited as snow on the northern hemisphere. Load deformations are modelled using the globally defined load Love numbers and a plate flexure model.

PROTEROZOIC TIDAL EVOLUTION OF THE DAY LENGHTH UNDER STOCHASTICAL PLURALMODE RESONANT APPROACH.

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As it follows from paleontological and paleosedimentological data analysis, the mean speed of evolution of the length of a day during Proterozoic appeared to be much less than that of Phanerozoic. As it was mentioned in my abstracts for the EGS Assembley 1995 this phenomenon could be explained by simultaneously decreasing of tidal period and average ocean depth if the hypothesis of average depth time dependence presented in the book of Sorochtin&Ushakov "Earth Global Evolution"(Moscow 1991) is accepted. These results were obtained on the base of continental paleogeographic reconstructions of Monin etc. 1986. The calculations performed on the base of Pangea hypothesis of Piper et. al show us that slower tidal evolution during Proterozoic could occur also for present and time variable ocean depths (EGS Abstracts 1996). The estimates based on averaging the power spectra of tidal output during geological epoches confirm these results.

THEORY OF THE EARTH'S ROTATION AT DIFFERENT TIME-SCALES

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The rotations of the Earth and of the core are investigating using the angular momentum theorem at different time-scales, for a mantle having a Maxwell model of rheology.
At a time-scale in the range the day to the decades, the Earth has an elastic behaviour. The atmosphere is responsible for perturbations in the polar motion and in the length of day (lod) over periods less than 2 years. At decadal time-scale, the angular momentum of the core (computed from the velocity field at the Core-Mantle Boundary (CMB) from the secular variation of the geomagnetic field) is correlated with the lod. Different kinds of core-mantle coupling are proposed.
At secular time-scale where the mantle is assumed to be viscoelastic, there is a shift of the polar motion of about some centimeters per year toward Canada which is explained by the post-glacial rebound induced by the Pleistocenic deglaciation. Various viscosity models of the mantle have been tested, for a linear theory of rotation.
At geological time-scale, where the Earth has a quasi-fluid behaviour, the temporal evolution of the mantle density heterogeneity involves a non-linear shift of the Earth's rotation vector, called the True Polar Wander (TPW). The influence of a blob sinking vertically into the mantle on the TPW has been investigated, assuming a physical or chemical boundary at 670 km depth.

TIME VARIABLE SPECTRUM OF THE FREE-CORE NUTATION

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The parameters of the Free-core nutation (FCN) mode can be determined from the VLBI observations of the celestial pole offsets. We analysed two time series of $d\psi$, $d\epsilon$ determined by the USNO in 1984.0–1997.8 and by the IERS in 1984.0–1997.5. Applying the Least Squares method the annual oscillation was removed from the $d\psi$, $d\epsilon$ data. The time variable spectra were computed using the Fourier Transform band pass filter (FTBPF) and the Wavelet Transform (WT) methods. The computed spectra, in the period range of 300–470 days, show the FCN oscillation with a period of about 416–420 days and variable amplitude of the order of 0.2–0.3 mas.

SUBDIURNAL VARIATIONS OF EOP FROM VLBI DATA

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Very Long-Baseline Interferometry (VLBI) is an observational technique which is able to measure a lot of tiny natural effects: pole motion, velocity of the Earth rotation, nutation, tectonic motion of continents, etc. But up to now the strong potential of VLBI technique has not been realized completely because routine solution from 24-hour session provides us only one-day estimates of EOP and subdiurnal variations are not available. Fortunately, it is possible to apply least squares collocation method (LSCM) for get the high-frequency estimates of parameters under study directly. The method takes into account an internal correlation between single VLBI scans. Following the LSCM one can consider the subdiurnal EOP variations as a stochastic process and make use apriori information (autocorrelation function) for adjustment procedure. It allows to obtain the EOP estimates with high temporal resolution corresponding to rate of VLBI experiment performance (1 value per 3-5 minutes) VLBI data from CONT'94 and CONT'96 intensive campaigns have been adjusted using LSCM. Time series of pole motion and the Earth rotation variations were obtained. Subdiurnal variations in UT1-UTC due to both forced as well as free oscillation effects in World Ocean are discussed.

LONG SERIES OF EARTH ROTATION PARAMETERS AFTER RE-ANALYSIS WITHIN THE HIPPARCOS FRAME

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The Earth rotation parameters (ERP) in the interval 1899.7–1992.0 are obtained from re-analysis of the observed latitude/universal time variations by optical astrometry. Hipparcos Catalogue is used to define the celestial reference frame, within which the ERP are described, with special care devoted to 'problematic' double and/or multiple stars. The terrestrial reference frame is defined by the adopted latitudes/longitudes of participating instruments and their secular motions as given by the NUVEL-1 NNR model of plate motions. More than four million observations with 48 different instruments at 31 observatories located all over the world are utilized to determine polar motion, celestial pole offsets and (after 1956) universal time UT1, all at 5-day intervals. Along with these parameters, the combinations of Love numbers, governing the tidal variations of the local verticals at the observatories, are also determined. The preliminary analysis of the results obtained are presented.

MONITORING EARTH ROTATION VARIATIONS BY GPS

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Over the past years GPS has become an important tool for the estimation of global geodynamic parameters. At present polar motion as well as variations of universal time are been determined daily by organizations participating in the International GPS-service for Geodynamics (IGS) with an accuracy of +/-0.1 mas and +/-30microsec respectively. In addition subdaily ERP-series with a time-resolution of 2 hours are available since 1995.
This presentation tries to summarize the most recent results obtained at CODE concerning the effects of the ocean tides on ERPs at subdaily time scales. Furthermore some aspects concerning polar motion and lod changes caused by atmospheric angular momentum exchange with the solid earth at periods of 1-2 days are also discussed.

G14 Contribution of permanent geodetic network to Earth Science in Europe

Convener: Calais, E.
Co-Convener: Ambrosius, B.A.

ACTIVITY OF THE LAMKOWKO IGS PERMANENT STATION

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Lamkowko Satellite Observatory is located in Northern Poland. It is one of three polish IGS (International GPS Service for Geodynamics) station. The main monument of our observatory, named LAMA, is the point of the IGS network and EUREF (European Reference Frame) permanent network. GPS observations are made using Turbo Rogue SNR-8000 and Ashtech Z XII receivers. Operation of these receivers is controlled by the Rubidium Frequency Standard. Results of GPS observations are used in global geodynamic research and also in many regional programs:

- EXTENGED SAGET (Satellite Geodynamic Traverses)
- CERGOP (Central European Regional Geodynamic Project)
- BSL (Baltic Sea Level) Project
- GEODUC (Geodynamics of Ukrainian Carpathians).

Results of GPS measurements are used in our own studies comprising:

- monitoring of the vector Lamkowko-Borowiec and other vectors
- ionospheric TEC variation determination at middle latitudes.

Ionospheric research are carried out by Institute of Geodesy, Olsztyn University of Agriculture and Technology in co-operation with West Department of the Institute of Geomagnetism, Ionosphere and Radio Wave Propagation of the Russian Academy of Sciences in Kaliningrad.

COMBINATION OF VLBI, GPS AND SLR OBSERVATIONS AT THE OBSERVATION LEVEL – FIRST RESULTS

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A significant number of VLBI and SLR stations are equipped with GPS receivers. A few true fundamental stations with all three techniques even exist. Each technique has its strength and weakness with respect to the determination of geodetic parameters and together they complement each other in a way that should be fully taken advantage of in the data analysis. The simultaneous analysis of different data types at the observation level, due consideration of the physical interrelations, and presentation of results in a common reference system, are the main ideas behind the development of the GEOSAT software. A new and improved version of the software has been implemented with an automatic generation of 1) consistent (at the 0.1 ppb-level) observation residuals, and partial derivatives for VLBI, GPS and SLR, and 2) a simultaneous arc-by-arc UD-filtering. The main elements of the program design and the first results will be presented.

STATUS AND PERFORMANCE OF THE GERMAN PERMANENT GPS NETWORK GREF-PERMANENT

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The Federal Agency for Cartography and Geodesy is installing, maintaining and operating a permanent GPS network of about 20 stations in Germany. This network is enlarged by the inclusion of several European EUREF permanent stations. It is further densified through the addition of permanent stations of the federal state's survey authorities. Since middle of 1996 the BKG computes daily solutions for a set of German and European permanent GPS stations using the Bernese GPS software. Loosely constrained solutions are generated and analysed to investigate kinematic effects and their influences on geodetic reference systems in Central Europe and the Mediterranean area.
The time series of co-ordinates available today cover a period of more than three years. Regional velocities are compared with NUVEL model velocities. The time series are analysed in view of short and medium scale variations. Details of the time series analysis are given. Model calculations are presented and their significance for GPS data processing is discussed. The relation of obtained results with tidal deformation and possible other effects is going to be studied.
The paper discusses the status and the further activity concerning the deployment, analysis and usage of GPS permanent stations in Germany.

THE ESTABLISHMENT OF A PERMANENT GEODETIC NETWORK IN THE UK

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The IESSG at the University of Nottingham is currently involved in a number of collaborative research projects using Continuously Operating GPS Receivers (COGRs) in the UK. These projects have led to the establishment of a permanent geodetic network of twelve COGRs, which is being used for a wide range of environmental research.
Five of the COGRs are located at major tide gauges, and have been established for the monitoring of vertical land movement in relation to changes in mean sea level. One of these five, and two further COGRs are sited along the River Thames in London, and were established in order to monitor changes in regional ground level in this low lying river estuary, in relation to flood defence. The other four COGRs are located at Meteorological Stations, and were established in conjunction with the EC funded WAVEFRONT project, which is related to the estimation of atmospheric water vapour for climatological and meteorological applications.
This paper provides details of the permanent geodetic network in the UK, and presents a summary of the preliminary results from the research projects.

THE SOUTHERN CALIFORNIA INTEGRATED GPS NETWORK

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The southern California Permanent GPS Geodetic Array (PGGA) was established in the spring of 1990 to evaluate continuous GPS (CGPS) as a new tool for monitoring the crustal deformation cycle and assessing earthquake hazards. The destruction caused by the 1994 (Mw=6.7) Northridge earthquake spurred a four-fold increase in the number of continuous GPS sites within two years of this event, with a concentration in the Los Angeles Metropolitan region. The PGGA is now the regional component of the Southern California Integrated GPS Network (SCIGN) of 50+ sites; SCIGN will be expanded in 1998-1999 to 250 sites throughout southern California but with a primary focus on the Los Angeles metropolitan region. SCIGN is a collaborative effort of scientists and staff at Southern California institutions under the umbrella of the Southern California Earthquake Center (SCEC). SCIGN operational centers are located at Jet Propulsion Laboratory, Scripps Institution of Oceanography, and U.S. Geological Survey (Pasadena). We describe the particular features adopted by SCIGN for monitoring small crustal deformation with the highest accuracy and reliability, and adequate spatial andtemporal resolution.

USING THE EUREF PERMANENT GPS NETWORK TO DETECT DEFORMATIONS WITHIN THE EURASIAN PLATE

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In 1995, the IAG subcommission "EUREF" took the initiative to establish a permanent GPS network in Europe for the maintenance of the European Reference Frame. The underlying reference system, called "ETRS89" is fixed to the stable part of the European plate and its yearly realizations create the homogeneous European reference to which local European GPS campaigns and permanent GPS arrays should be linked.
The EUREF network presently consists of 64 tracking stations covering 23 countries, going from Greenland to Turkey.
The aim of this paper is to assess the quality of the velocities computed with the more than two years of weekly EUREF solutions presently available. In order to obtain motions within the European plate, no a priori velocity model was used. The majority of the resulting "European" horizontal velocities is of the mm level. Due to the very small velocity vectors, it is clear that great care is necessary with their interpretation, even though permanent GPS sites have been used. The paper investigates the possible error sources, such as insufficient high quality data, changes at the antenna or its environment and computation related effects.
Finally, recommendations are made in order to improve the use of the EUREF permanent network for crustal deformation studies.

SOUTH SPAIN-NORTH AFRICA GEODYNAMIC GPS NETWORK

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The "Ibero-Magrebian" region includes the Iberian Peninsula: Gulf of Cadiz, Alboran Sea and the North-Western part of Africa, and comprises a part of the westernmost Eurasia-Africa plate boundary. The main geological topics of the South Spain-North Africa area are: The Betic, Rift and Tell Mountain belts, western limit of the Alpine orogenic belt. The seismicity is characterized by moderate magnitude earthquakes (M<5), but the ocurrence of destructive ones in the past is documented (M=8). Intermediate (90 km) and deep activity (650 km) is registered. The regional stress pattern, derived from fault plane solutions, is N-S to NW-SE horizontal compression. The NUVEL-1A plate motion model predicts for this area a continued NW-SE convergence of Africa and Eurasia at a rate of 5 mm/y. To study this convergence, several selected sites located in the south Spain and north Africa, have been monumented and GPS observed during 1994, some of them were reobserved in 1996. A new complete reobservation field campaing has been fund, to be developed in the period 1998-1999. Meanwhile a permanent IGS site (SFER) has been installed (1996) at San Fernando Observatory (Cadiz) and a new permanent GPS site will be installed in the first half period of 1998 at Melilla (North Africa). Observations have been already carried out in Cartagena (SE of Spain), in order to complete a permanent GPS geodynamic triangle (S. Fernando-Melilla-Cartagena) covering this broad deformation area.

A PERMANENT GPS NETWORK FOR MONITORING CRUSTAL DEFORMATION IN THE WESTERN ALPS.

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Within the framework of a scientific collaboration between the CNRS-INSU, the universities of Nice, Grenoble, Chambery, Montpellier, the Observatoire de la Cote d'Azur (CERGA), the Institut Geographique National (LAREG) and the Institut de Protection et de Surete Nucleaire (CEA), a network of permanent GPS stations is currently being installed in France in the Western Alps and their foreland. The scientific objective is primarily crustal deformation monitoring, but this permanent GPS network will also serve atmospheric (tropospheric water vapor and ionospheric electron content) as well as surveying applications. As a first step, 4 stations are installed near Lyon, Chambery, St Jean de Maurienne and Modane, in order to provide a transect (including the permanent station of Torino) that samples each of the major tectonic blocks. In the southern Alps and Provence, two stations are installed in the Luberon and at Cadarache on each side of the Durance active fault zone, in addition to the existing IGS site at Grasse supported by CNES. Additional stations will be installed in 1998. We present the status of the network and preliminary deformation results in the Western Alps based on 2 years of continuous GPS data at Grasse, Torino, and Zimmerwald.

THE ITALIAN GPS FIDUCIAL NETWORK IN ITALY, PRESENT STATUS AND FUTURE DEVELOPMENT

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The Italian GPS Fiducial Network has been established since 1995 when the Italian Space Agency installed 5 GPS receivers in sites co-located with other Space Geodetic Techniques (Cagliari, Noto, Medicina, Matera) or with tide gauges (Venezia). The main goal of such effort is to densify the global GPS network, to perform intercomparisons between terrestrial reference frames established with different Space Geodesy tecniques, to monitor the sea level change, to support studies of crustal movements and local geoid. In the last years this effort has been integrated with contribution of various Italian Institutions and today a very dense network of more than twenty permanent receivers is suitable in order to study a very complex area from the tectonic point of view. Furthermore GPS technique is widely used also in other fields of investigation such as atmospheric physics and Earth's global change. So the efforts of the Space Geodesy Centre are addressed to fully exploit opportunities that a so dense and well distributed network is able to pursue. In particular we are focusing our attention on the new products and services that a permanent GPS network can provide to a very large community of scientific users.

THE REGIONAL VLBI-NETWORK FOR MEASUREMENT OF CRUSTAL MOTION IN EUROPE - STATUS AND RESULTS

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At present, the European geodetic VLBI network consists of ten stations with six core stations participating since its first joint session in early 1990. The operation of the network is organised, correlated and analysed by the VLBI group at the Geodetic Institute of the University of Bonn. Geodetic analyses are also being performed by several other participating groups. The network has been operational since the late eighties starting with three sessions of 24 hours each per year. For five years now the sessions have been scheduled in bi-monthly intervals. Since 1993 the operations have received financial support under two consecutive EU-Programmes (Science and Training & Mobility).
Baseline length changes and station drift rates have been derived from the data with steadily increasing accuracy. The motions detected so far are rather small, i.e. on the order of one to six millimeters per year. The overall picture of these motions agree very well with the pattern of tectonic motions based on geophysical data. Recent analyses are made to emphasise vertical motions, which are even more difficult to detect due to the negative effects of tropospheric path delays.
This paper describes the most recent analyses and depicts the results of baseline related computations as well as station drift rates in a Europe fixed frame.

CONTINUOUS MONITORING OF EARTH ATMOSPHERE AND CRUSTAL DEFORMATION USING GPS

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Several nation wide and continuously operating GPS networks have been established in northern Europe since 1993. Today, more than 50 permanent stations are available in the region. Data from the majority of these stations are analyzed daily. The product data base now consists of more than 1500 days of continuous observations and solutions of a row of parameters.
Project BIFROST uses permanent GPS networks to determine 3-D crustal motion in Fennoscandia. We show vertical and horizontal rates of relative site motion determined with uncertainties now approaching 0.3 mm/yr and 0.08 mm/yr, respectively (95% conf). The product data base provides a unique resource for the analysis of regional deformation.
We also study the possibility to use continuously operating GPS networks to monitor the ionospheric total electron content and the atmospheric water vapor content. Estimates of atmospheric parameters obtained from GPS are compared to those from other techniques. Especially, long time-series of GPS-derived atmospheric water vapor at Onsala is compared to observations by the colocated microwave radiometer.

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INVESTIGATION OF SPECIFIC PERIODS FOR CRUSTAL LOADING EFFECTS ON GPS BASE "MENDELEEVO - IRKUTSK"

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A software for calculation of crustal loading deformations for stations within Eurasia is developed. The input data are daily data of the atmospheric pressure in trapezoid top with a step of 5 degrees in latitude and 10 degrees in longitude in the north hemisphere. A calculation algorithm is constructed with regard to Farrel model using Green function. A spectral analysis of two year series of calculated and measured data using GPS observations of crustal loading deformations in Mendeleevo (Moscow region) and Irkutsk sites is made. Typical deformation periods and amplitudes depending on the season are defined. Correlation evaluation between calculated and measured deformations is performed. The obtained data are compared with calculations of another authors. Organization of the Center for operative calculation of deformations at the Institute of Metrology for Time and Space and their publication is proposed.

ON BSL'93 COMBINED GPS SOLUTION

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Six analysis centers presented a solution for the Baltic Sea Level 1993 GPS campaign (BSL'93). Analysis of the discrepancies between these individual solutions shows that the internal accuracy of the existing combined solution can be considerably improved. Therefore the individual solutions were compared using a seven-parameter Helmert transformation. A new combined solution was derived using the transformation parameters determined from the comparison of the individual solutions. Finally, the combined solution was transformed to the ITRF'94 system. The internal accuracy of this new solution is as much as three times better than exiting one. The transformation of the combined solution to the ITRF'94 system cannot be derived very accurately due to the poor distribution of the fiducial stations. Additional fiducial stations are needed for the Eastern part of the Baltic region to achieve the best orientation of network. A additional problem is that all, but one, individual solutions were computed without accounting for the antenna phase center variations. To avoid systematic difference between the BSL'93 and BSL'97 results it is necessary to process the observations made during these campaigns (and, maybe, also the BSL'90 campaign) using the same (modern) models, particularly models for the antenna phase center variations. Furhtermore, it would be desirable to use individual daily solutions to derive a more accurate combined solution.

PACIFIC NORTHWEST GEDOETIC ARRAY (PANGA)

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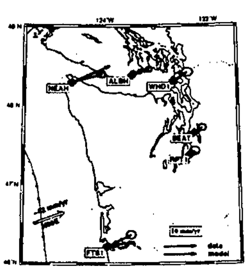
The Pacific Northwest Geodetic Array (PANGA) is a permanent array of high precision Global Positioning System (GPS) receivers established in 1995, as a result of a collaborative effort between the University of Washington, Central Washington University, Oregon State University, Rensselaer Polytechnic Institute, University of Oregon, the United States Geological Survey, and the Geological Survey of Canada. Its primary goal is to monitor deformation of the earth's crust and its impact on earthquake and volcanic hazards in the Pacific Northwest United States. Currently, PANGA consists of 20 stations spanning the Cascadia Subduction Zone (CSZ) from northern California to southern British Columbia Figure shows the comparison of the observed and modeled crustal velocities with respect to North America plate. The data is based on more than 2 years of daily solutions. For the predictions we used a 3D elastic dislocation model after Flück et al., 1997, which allows for a non-planar slab geometry, as well as varying slip rates along the fault surface. As can be seen from the figure, the observed and modeled deformations are in good agreement. For more information regarding PNAGA visit *http://www.geophys.washington.edu/*GPS/



FIRST OBSERVATIONS FROM *C*RETE *RE*GIONAL *T*ECTONIC *E*XPERIMENT (CRETE).

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The island of Crete, in Greece, located in the forearc of the Hellenic subduction zone with intense seismicity, is a natural laboratory for deformation monitoring which steers the establishment of a regional GPS permanent array. The array comprises a base station at Chania, a second permanent site collocated with the tide-gauge at the Naval Base of Souda, near Chania, and the incorporation of 3-4 sites previously used in GPS and SLR campaigns on Crete. Despite the remarkable similarity of the numerical-models-produced uplift rates with those observed and reported by Lambeck, competing underlying lithosphere and driving mechanisms models require validation through observations. In addition, Crete is, in general, characterized by very complex local motions beyond the dominant thrusting plate rate. Their detailed characterization requires a permanent, dense, continuously operating local network that allows monitoring of the motion without any assumption about its nature. Characterization of the three dimensional deformation field has also gained importance since vertical deformations contaminate tide-gauge-determined sea-level variation signals. The new GPS array (CRETE) will contribute in the densification of the IGS network in this region, in tide-gauge monitoring, seismic hazard monitoring, and DGPS navigation and surveying applications.

USE OF THE FINNISH PERMANENT GPS NETWORK IN POSTGLACIAL REBOUND STUDIES

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The Finnish Geodetic Institute has established a network of 12 permanent GPS stations in Finland (FinnNet). The network is used as a reference frame and as a source of data for numerous national and international GPS campaigns and projects. The network has been used as an important backbone of such GPS campaigns like EUVN (European Vertical GPS Reference Network), BSL (Baltic Sea Level) and national EUREF densification, EUREF-FIN. We describe the operations within the network, especially for geophysical purposes to detect the postglacial rebound of the Fennoscandian crust. Connections to other similar projects, like DOSE (Dynamics of the Solid Earth) and BIFROST (Baseline Inferences for Fennoscandian Rebound Observations, Sea Level and Tectonics) are discussed. We will also present the performance of the network, the expected accuracy one can achieve in geophysical studies, and results of the data analysis during the major history of the network.

THE REDESIGN OF THE BELGIAN PERMANENT GPS NETWORK FOR FUTURE (NEAR) REAL-TIME APPLICATIONS

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Presently consisting of 7 permanent GPS stations, the Belgian permanent network was primarily set up by the Royal Observatory as a reference network for national geodetic applications and as a basis for the study of the influence of the ionospheric refraction on GPS geodesy and the repeatability of the GPS-based coordinates. As for most national permanent GPS networks, a part of the stations belongs to the IGS/EUREF network.

Taking into account the growing interest for (near) real-time applications, with a higher sampling rate, the original implementation of the network, consisting of daily telephone line transmission of 30 sec. data, has been reviewed.

The aim of this paper is to present the current research work towards this goal : real-time data and receiver monitoring, a variable download interval, a selectable transfer interval, a receiver independent compressed data format and concurrent data transmission from the network of remote stations to the central processing facility. All actions are timed by GPS.

An analysis of available transmission channels demonstrates that an Internet access via an Internet Service Provider offers most opportunities towards a flexible and polyvalent system. The developed software exploits the firm integration of the Internet protocol with the multi-tasking capabilities of LINUX.

Three-dimensional crustal deformations in Europe observed with space geodesy

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This paper addresses the analysis of space geodetic observations taken by various networks of stations in Europe and interpret the results, in particular in terms of crustal deformations. Characteristics of the dataset analyzed are its diversity (it is a combination of 2 techniques: Satellite Laser Ranging and Global Positioning System), the long time-interval which is covered (1983-1997), the high quality of the results (typically 5-20 mm for an epoch position solution) and its wide geometric distribution (the dataset comprises some 40 stations which cover Europe reasonably well). Because of the variety in contributions, the time-frame covered and the scientific demands, the proper combination of the data and the reduction to a suitable reference frame are crucial elements of the investigations. The resulting deformation estimates have a typical accuracy in the order of 1-2 mm/year. As for their geophysical interpretation, the paper will discuss relative (internal) deformations, the 3-dimensional motions of individual stations and the deformation regime and strain rates within Europe.

THE SEVEN-YEAR HISTORY OF THE BALTIC SEA LEVEL GPS CAMPAIGNS

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The Baltic Sea level project (BSL) was initiated in 1989, and the first GPS campaign was arranged in 1990. After that, two other GPS campaigns, in 1993 and 1997, have been arranged, the latter one combined with the EUVN (European Vertical GPS Reference Network). One of the goals of the BSL is to unify vertical datums of the countries around Baltic Sea. This can be achieved already in the centimeter level. From the repeated observations one can study also the sea-level variation and land uplift of the area. We present the results of the 1997 GPS campaign, and combine them with the results of the previous ones. We also discuss on the problem of the reference frames and use of permanent GPS networks of the area to tie observations made at different epochs to the same system.

Continuous monitoring of crustal deformation along the Dead Sea Fault utilizing a permanent GPS network

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The Dead Sea Fault (DSF) is a left lateral strike-slip fault, separating the Arabian plate from the Sinai sub-plate. The relative plate motion across the fault was estimated in the range of 0-10 mm/yr. The higher values reflect the average long-term (million of years) motion across the fault, whereas the lower ones reflect the low to moderate level of seismic activity along the fault. By using an array of permanent GPS sites in Israel, we measure the current rate of motion across the DSF. The network includes 4 sites, 3 operated by the Survey of Israel and the 4th by Tel Aviv University. The first year of observations (July 1996 - July 1997) revealed a very low rate of motion across the fault (0.6$\pm$0.6 mm/yr). Even when we considered an elastic strain accumulation adjacent to the fault, by using a simple locked fault model, we still obtained a very low rate ($\le$ 2 mm/yr) of motion across the DSF. Our results suggest that during the first year of observations, the current plate motion between Arabia and Israel-Sinai was significantly lower than the long-term geological average rate. Although this conclusion has important implications for seismic hazard assessments in the eastern Mediterranean region, it should be viewed very carefully, because our calculations are based on a short observation time.

OWAG-B: A PILOT PROJECT FOR OPERATIONAL WATER VAPOR ESTIMATION IN A DENSE GERMAN GROUND-BASED GPS NETWORK

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During the last decade numerous ground- and space-based remote sensing techniques were developed for measuring different meteorological parameters. The estimation of water vapor is the most complicate one, and the knowledge of its distribution is yet insufficient. However, water vapor is the dominant parameter in the hydrological cycle. Therefore, continuous and well-distributed measurements of water vapor are of crucial importance for numerical weather predictions and climatological studies. The GPS technology offers an effective instrumentation for its determination. In the European Union COST Action 716 a feasibility study for the use of GPS-derived integrated water vapor in data assimilation software for weather prediction will be performed. Within this framework a cooperation between GFZ and the German Meteorological Service (DWD) is planned. In a first step a pilot project will be set up where in a permanent German GPS network the operational determination of water vapor should be demonstrated. The project comprises all necessary components - data links and handling, path delay estimation, met data interpolation to GPS location, inversion to water vapor. This contribution will give an insight into all components of the planned system and will demonstrated the capabilities of methodology used by GFZ on the basis of real data as well as the strategy to come from scientific experiments to an operational day-to-day service.

UNIVERSITY NAVSTAR CONSORTIUM (UNAVCO) FACILITY SUPPORT TO PERMANENT GLOBAL POSITIONING SYSTEM (GPS) NETWORK INSTALLATION AND OPERATION

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The UNAVCO Facility in Boulder, Colorado supports investigators funded by the U. S. National Science Foundation (NSF) and National Aeronautics and Space Administration (NASA) in installing and supporting permanent Global Positioning System (GPS) stations and networks on a worldwide basis. UNAVCO has supported the installation of over 70 stations in the western U. S., Mexico, South America, Central America, eastern Mediterranean, central Asia, China, Greenland, India and western Pacific regions. Many of these stations are contributing to the International GPS Service for Geodynamics. In supporting these installations, UNAVCO has developed capabilities that are publicly available via the UNAVCO Home Page (http://www.unavco.ucar.edu) and can be easily adapted by other groups for their specific applications. UNAVCO is extremely interested in collaborating with other international organizations to gain insight into their technology development related to permanent GPS stations and to expand and improve the capabilities outlined above for future GPS measurement applications.

BIFROST PROJECT: HORIZONTAL AND VERTICAL CRUSTAL MOTION IN FENNOSCANDIA FROM 1500 DAYS OF CONTINUOUS GPS OBSERVATIONS

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BIFROST GPS observations [Johansson et al., this session] are used to derive 3-D crustal motion in Fennoscandia relative to a rigid frame designated to travel on average with the Eurasian plate. In the *horizontal components* the deviatoric motion with respect to a rebound model (120 km lithosphere thickness, 1×, 2×10^{21} Pas upper resp. lower mantle viscosity) are at a level below 1 mm/yr ($\chi^2 \simeq 20$)). The apparently predominant pattern of motion shows extension without azimuthal dependence. This suggests postglacial rebound to be at least one order of magnitude more important than other processes for explaining ongoing movement. More localized movement, e.g. near shear zones apparent in the geology, is probably confined to a scale below 200 km and/or rates of 0.1 mm/yr or less.
The observed *vertical motion* compares well with postglacial rebound models. Using tide gauge results inferred geoid rates are still problematically high However, as the data base grow we are sble to demonstrate a trend towards lower rates as perturbations due to site related problems become smaller and consistency of reference frame improves.

PHASE SURGE ANOMALIES: DESCRIPTION, ORIGIN AND SOLUTION

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Careful observation of data from GPS reference stations in the EUREF network shows unexpected surge-like anomalies in the "geometric free" combination of phase measurements. This so-called phase surge hits all stations equipped with a receiver tracking under the Cross-Correlation mode (like TurboRogue or Trimble SSE) and affects all satellites under Anti-Spoofing, whatever their elevation. Taking into account only satellites above 20 degrees, an average of 15 such surges can be observed every day in 1 second data files. Their amplitudes range from a few centimeters to tens of meters. The phenomenon has been found to be caused by interferences between satellites signals. Although not dramatic in post-processing where the perturbed data are automatically discarded by the processing software, it has major adverse impact on the real-time data analysis: it is the major source of cycle slips on L2, it is likely to be misinterpreted as an ionospheric phenomenon and it fools the traditional monitoring algorithms. The aim of this paper is to give a characterization of the phase surge phenomenon, to explain its origin in the receiver architecture, and to discuss its consequences on data monitoring and on ionosphere analysis. A detection and an adapted monitoring algorithm are presented.

IMPLEMENTATION OF GIPSY FOR THE ANALYSIS OF LARGE CONTINUOUS GPS NETWORKS

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The computational burden from the daily analysis of GPS data from large ground networks of receivers can be significant with the processing time being proportional to the cube of the number of parameters estimated. For data from the Southern California Intergrated GPS Network (SCIGN) and the 890 station network of the Geographical Survey Institute of Japan (GSI), the GIPSY software is used to reduce this burden through precise point positioning. With this technique, each station is individually positioned using precisely determined orbits and satellite clocks. This technique simplifies many of the computational issues and allows for efficient distribution of the processing among different CPUs, resulting in processing time that is roughly linearly proportional to the number of stations processed and inversely proportional to the number of CPUs available. Average daily station coordinate repeatabilites using precise point positioning are a few mm in the horizontal and less than a centimeter in the vertical coordinates.

MIXED GEODETIC NETWORKS FOR EARTH SCIENCES

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Observations from local geodetic networks can benefit from the establishment of a regional reference system for a broader interpretation of measures of tectonic deformation, post-glacial rebound and sea level monitoring. The world-wide system of IGS stations can be used to provide the reference frame for GPS networks, supplemented by measurements from nearby instruments which employ alternative space techniques. In order to place the geodetic observations in a global, inertial reference system, the capabilities of SLR, VLBI, DORIS and PRARE instruments can be used and this will further extend the interpretation of the measurements. However, rigorous definition of the reference frame for parameters such as the velocity field requires observations taken during the same time period unless we assume that the station motion is uniform. We present here measurements of the horizontal and vertical behavior of the permanent European network of SLR observatories, some of which have been providing accurate position measurements for 15 years. Evidence for unsteady motion at the observatories is examined and we explore the challenge of combining these results with position measurements derived from observations from the other space techniques, many of which have been in operation over a more limited time span.

SATVB - A MULTIPURPOSE GPS-REFERENCESTATION NETWORK IN AUSTRIA

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In 1997 the BEWAG, a local power supply company in Austria, established in cooperation with the Department of Theoretical Geodesy in Vienna a network of 4 permanent GPS reference stations. The goal was to spread RTCM corrections at 75 MHz over the service area of the company for GPS real time applications. The reference stations are interconnected by means of a wide area token ring network which allows for the computation of atmospheric models and correction parameters for distance dependent errors in realtime. Observation data recorded at the permanent stations has been processed at a daily basis since December 1997. The resulting time series allow for investigations concerning the ionospheric and tropospheric behaviour as well as for studies of multipath effects.

ACTIVE GPS REFERENCE SYSTEM FOR THE NETHERLANDS

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In 1995 Rijkswaterstaat, the Cadastre and the Delft University of Technology started to build a network of five permanently operating GPS receivers in the Netherlands. Locations were selected to have a good connection to other techniques, such as SLR, VLBI and levelling. Also, one of the stations is co-located with a tide gauge at the North Sea coast, which is of interest for the monitoring of sea level changes. The full network is in operation since the beginning of 1997. The network is currently being used in combination with the Fifth Primary Levelling of the Netherlands, during which a large number of fundamental height benchmarks are surveyed using GPS and primary levelling techniques. The permanent network is also used for surveying, atmospheric water vapour retrieval and geodetic research.
The data from the permanent stations is sent every hour to a central computing centre, from where the data can be downloaded using the World Wide Web. Users may specify various time intervals and data rates. The latest development is that data is computed on-line (from a network adjustment) for specific locations and users, resulting in a so-called *virtual* GPS reference station.
This presentation will focus on the design of the network, the method of data distribution and its applications.

THE NEW GEODYNAMIC SITE IN LATVIA LV-04 (IRBENE) CONVERTED RUSSIAN EX-MILITARY OBJECT

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Abstract: The second geodynamic site (after *Riga - Botanical garden* with SLR and permanent GPS) has been established in Latvia by Ventspils International Radio Astronomy Center (VIRAC) and Astronomical Institute University of Latvia (LU AI). The site name is *LV-04 Irbene* with coordinates ϕ=57°33'.29, λ=21°51'.13. The first GPS measurements have been performed during EUVN'97 and BSL (Baltic Sea Level) campains the last May, using Trimble 4000 SSE receiver of the State Land Survey of Latvia. From early 1998 the permanent GPS receiver from Onsala Space Observatory (Sweden) hopefully starts operations in Irbene and during 1998 the basement for absolute gravimetry will be finished. Geodynamic site *LV-04 Irbene* has been established by reconstruction of several buildings of russian ex-military base near Ventspils. Specialy designed GPS antena holder was constructed on ancient small radio telescope basement to obtain practicaly open horizont. Site *LV-04 Irbene* is situated about 200 m from VIRAC's 32-meter fully steerable radiotelescope antena RT-32 and 500 m from 16-meter radiotelescope antena RT-16, aimed to participate the VLBI activities in the nearest future.

G15 Instrumental challenges in geodesy

Convener: Tomasi, P.
Co-Convener: Degnan, J.J.

MONITORING SLR RANGE BIAISES FROM MULTI-SATELLITE LONG TIME SERIES OF LASER RESIDUALS

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Satellite Laser Ranging (SLR) is a major technique in space geodesy particularly for the satellite orbits and the site positions to be accurately determined. In view of important scientific challenges to be realized in geodynamics and oceanography, it is very important to be able to properly separate geophysical (e.g., the effects of mass redistributions) and instrumental (e.g., calibration biaises) error sources at the level of one cm locally and 1-2 mm / year.
The recent improvements of the precise orbit determination models and methods have permitted analysis of homogeneous long time series of laser orbit residuals. We have performed a cross analysis of 5 years (92 to 97) of laser residuals on LAGEOS (1 and 2) and TOPEX/Poseidon satellite orbits, for which orbit errors are now at the level of 3-4 cm. Strong correlations between signals have been identified for most of SLR stations, permitting the evolution of calibration biaises of their instrumentation to be quantified. We show this analysis is going to play an important role in the determination of orbits and especially of the terrestrial reference frame.

ACCURACY VERIFICATION OF PRARE MEASUREMENT DATA AND CALIBRATION TECHNIQUES

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The two-way microwave satellite tracking system PRARE is in continuous operation onboard ERS-2 since May 1995. Performing simultaneously range and range-rate measurements at the sub-dm and sub-mm/s accuracy level to up to four ground stations at the same time, the system has proven to be a valuable and highly accurate data source for various geophysical applications. The basis for the high accuracy is the dedicated measurement principle: a set of fully coherent, dynamically highly stable delay- (DLL) and phase-locked loops (PLL) inside the space segment, driven by one central quartz oscillator (VCXO). As both the short- and the longterm stabilities of this oscillator are excellent, the system is ideally suited for deriving uniform, consistent longtime data series. Also the signal and data modulation structure, which is formed by truncated, medium-periodic pn-codes (1 and 10 MHz), twofold modulated by coherent, regenerative carriers (8.489 and 2.248 GHz) and high-rate binary information with time marks (2, 4 or 10 kbps), is fully appropriate.
It will be outlined that the technical instrument design is most favourable to assure a stable system performance under all operational circumstances, e.g. multipathing. The various calibration efforts carried out at the central PRARE data processing facility, the Master Station Oberpfaffenhofen, maintain the technical measurement precision and stabilize the system significantly.

ADVANCED NASA RESEARCH AND DEVELOPMENT IN SATELLITE LASER RANGING

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Since its first successful demonstration by NASA in 1964, the precision of Satellite Laser Ranging (SLR) to artificial satellites has improved by three orders of magnitude, i.e. from a few meters to a few millimeters. This long-standing and highly mature space geodetic technique has contributed significantly to scientific studies in virtually all areas of geophysics and to lunar physics and relativity as well. As we enter the new millennium, there are three SLR-related technological thrusts being pursued by NASA: (1) the improvement of range absolute accuracy by another order of magnitude through the use of multiwavelength techniques, picosecond timing, and improved satellite targets; (2) the development of the fully automated, eyesafe SLR2000 ground station for safer and more cost-effective operations; and most recently (3) extension of SLR beyond the Moon to the inner planets through the use of two-way asynchronous laser transponders. The current status in each of these research areas is reviewed including a summary of technological challenges encountered to date and our chosen or proposed solutions.

INDEPENDENT VALIDATION OF THE GLOBE GLOBAL DIGITAL ELEVATION MODEL USING SATELLITE ALTIMETRY

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The requirement for a global 1 kilometre Digital Elevation Model (DEM) is currently being addressed by the compilation of several near-global elevation datasets. One critical constraint in evaluating the accuracy of such models is the limited availability and quality of independent comparison data. At this spatial scale, altimetry presents an attractive option, with the combination of near-polar orbit and close track spacing during the ERS-1 geodetic mission providing data at a spatial scale of several km. However, to interpret these data effectively over land requires 'retracking' the complex echoes produced over topographically varying surfaces.
This paper presents a detailed examination of the GLOBE GDEM, using a retracked altimeter dataset from the ERS-1 geodetic mission, including every 1 degree tile of GLOBE land data for which altimeter derived heights are available. Regional and local discrepancies are analysed, quantified, and recommendations made to improve the GLOBE dataset.

TESTING OF VLBI SITE DATA ACQUISITION AND REGISTRATION EQUIPMENT WITH A CORRELATOR USE.

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Main purpose for testing of the data acquisition and recording systems at the radiotelescope is to clean whether the equipment has a rather good quality to be used for VLBI observing or not. Signal coherence losses in the interferometer channels and additional noise from local oscillators of microwave receivers, down converters, videofilters, clippers and formatters/deformatters may be found both for each device separately or for the all complex together. Radiotelescopes of QUASAR complex and particularly in Svetloye site contains calibrated noise generators working into microwave frequency bands (from 1,38HHz to 22,5HHz), intermediate frequency range of 100 to 1000MHz and with videofrequencies up to 32MHz, ps impulses generators and a compact mobil correlator for cross-correlation function of signals and phase fluctuation computing. Methods and results of experiments are described as well.

G15

PICOSECOND EVENT TIMER FOR MILLIMETER LASER RANGING

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To contribute to future Laser Ranging (Ground-Ground, Ground- Satellite, Ground-Moon, Satellite-Ground) we developed the Picosecond Event Timer (PET). PET consists of the event timing modules, clock generation module, control unit, range gate generator, personal computer and the software package. The main parameters : 1.2 psec timing resolution, < 8 psec time interval jitter, < 0.5 psec / Kelvin temperature stability, < 3 psec / hour temporal stability, 40 nsec range gate setting step, > 4 sec maximum interval, > 100 Hz repetition rate, > 1000 flying pulses. Using the cable delay line we have obtained 6 psec ultimate time interval jitter. Ranging to ground target (SLR Graz, G. Kirchner, F. Koidl), using the 30 psec YAG laser and the SPAD detector, we obtained 2.3 mm ranging jitter at several photoelectron signal level. Ranging to Lageos and ERS-2 test targets, we obtained the single shot jitter 7 and 4 mm, respectively. PET is connected to Start and Stop signals, to GPS receiver signals and via serial port to the personal computer. It is compact, occupying 19 inch by 10 inch rack unit, 28 kg weight, 160 Watts power consumption. The whole system is dedicated as a timing system for advanced laser stations and as a second generation Portable Calibration Standard, as well. The Dassault Electronique timing and clock modules are space qualified. However, upgrading up to less than 3 psec time interval jitter, 5 kHz repetition rate and multistop operation can be considered.

TIME WALK COMPENSATION AND SATELLITE SIGNATURE REDUCTION WITH SPADs

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The SPAD (Single Photon Avalanche Detector) has proven already its capability of timing single-photon events with picosecond accuracy; it does that also for multi-photon events, but introduces there a significant time walk effect; with received energies of 1000 photons and more, the measured epoch time is shifted 240 ps or more towards shorter times. This effect would introduce range errors of more than 35 mm, when measuring distances to satellites. It has been shown that this time walk effect is connected with a very mall change (about 20 ps) of the avalanche rise time; this effect has been successfully used to develop an electronic circuit which measures this rise time difference, and uses it to compensate automatically this time walk effect. Some versions have been built and tested successfully in different Satellite Laser Ranging Stations (Graz, Changchun, Tokyo, Grasse etc.). It has been shown that the time walk effect can be more or less reduced to zero, for the required full dynamical range (from 1 to 1000 photons). By measuring additionally the actual time walk for each return, the received energy can be determined; combining this with the theoretical mean reflection point on the satellite for this energy, the satellite signature can be identified and subtracted.

The EUROLAS stations as an effective satellite tracking cluster.

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The EUROLAS Cluster of Satellite Laser Ranging stations collects annually some 40% of the observations made by the world-wide SLR Network. The ongoing challenge of the SLR technique is to meet ever more stringent quality targets so that observations which have the potential to address a whole range of geodetic and geophysical problems may continue to remain at the forefront of space geodetic techniques. We have exploited the clustering of the stations to carry out a study into the precision and accuracy of routine observations of the Lageos satellites. We find that there is a core set of very accurate stations whose observations agree at the mm level, and we use these observations in a short-arc orbital improvement scheme to judge the accuracy of other stations in the cluster that are tracking the same satellite at the same time. We have fully automated this quality-check procedure, and present daily on the WWW the results in the form of graphs of range residuals, and numerical estimates of stations' time and range bias values. We have used such information on the expected quality of observations of the Lageos satellites from the stations to carry out a three-year solution for station range and time bias history, and have derived a new set of EUROLAS station coordinates within the ITRF94 reference frame. To check the validity of this set of coordinates and bias histories, we have used them to analyse by the short-arc technique some sets of range observations of ERS-2, and find that orbital arcs can be determined to a precision of a few cm. We conclude that observations from the EUROLAS Cluster of SLR stations and the continuing quality check procedure together will make an effective tool for calibration of for example the ENVISAT altimeter.

Real-time VLBI system for the Key-Stone Project

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We have developed a real-time VLBI system, using a high-speed ATM (Asynchronous Transfer Mode) network. In real-time VLBI, the observed 256 Mbps/station VLBI data is transmitted through 2.4 Gbps ATM communication network instead of being recorded onto magnetic tapes. The system was specially designed for the Key Stone Project (KSP), which is concerned with measuring crustal deformation using four stations in the Tokyo metropolitan area in Japan. Cross-correlation processing and data observation are carried out simultaneously, and it takes about two hours to analyze crustal deformation data after the VLBI observation is completed. The regular geodetic VLBI experiments, every other day's 24-hour experiments, horizontal position uncertainties of about 1 mm and vertical position uncertainties of about 10 mm, in a sense of internal estimation error evaluated by one sigma standard deviation, have been achieved. In the real-time VLBI, no human operation is realized to both the observation and the correlation processing. The system was designed to achieve automated operation throughout the entire process, the obtained results are opened to public via the internet (http://ksp.crl.go.jp).

MULTICHANNEL SOFTWARE CONTROLLED RADIOMETER FOR RADIOTELESCOPE IN S. SVETLOYE.

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Digital radiometer based on microprocessor 5012A Octagon was made as equipment for radiotelescopes of the VLBI QUAZAR complex. It works with radioastronomy receivers from 21cm to 1,35cm wavelength and is able to measure the signals power in up to 16 channels simultaneously at the bandwidth of intermediate frequencies (100...1000MHz) and videofrequencies (up to 32MHz). Processor stores and averages the measurement data with the error of $(1...2)\times10^{-5}$, and then transmittes them to the central computer, which controlles radiotelescope equipment according to the program. Measurements may be held both by simple detecting without modulation of signals in the receiver, and with modulation, including an assymetrical one. New algorythm of storing of the signal samples and the samples of the calibrated noise with different scales increases the sensitivity and preciseness of radiometer by 40%. In two-channeled modulated radiometer this algorythm allows to approach to the theoretical limit of the sensitivity of the ideal compensator without losses. Compact radiometer may work in difficult climate conditions and can be set up at the antenna. The first radiometer of that sort is used in s.Svetloye. The scheme, parameters and results of the tests of the radiometer are given as well.

THE ON-SITE DIAGNOSTICS AND ACCURACY IMPROVEMENT OF SATELLITE LASER RANGING STATIONS USING PORTABLE CALIBRATION STANDARD

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The quality control of precision and accuracy of the station is one of the biggest issues for Satellite Laser Ranging (SLR) network to perform as a geodetic calibrator of the other space-bone geodetic system and to establish mm level accurate terrestrial reference frame. We present the design, operation and performance of the portable calibration standard (PCS) as a tool of on-site diagnostic of SLR stations in Japan and China network. The PCS, a full electronic SLR equipment, consists of time interval counter, GPS time receiver, epoch counter, meteorological sensors, control PC and post processing package. We also deployed the bias free single photon detector and re-examination of local survey to the terrestrial calibration target. The Changchun session during August 1997 through follow-on experiment in the next two months have shown the results of (1) Improvement of single shot precision by factor three to 1 cm, (2) Consistency between survey and terrestrial ranging to calibration target improvement by factor three to 4 mm, (3) Meteorological Sensor calibration to 1mm, and (4) Stability of Range bias derived from LAGEOS global orbit bias analysis improved by factor two to 25mm. Those will contribute to the regional and global geodynamics program.

APPARATUS FOR COMPLEX INVESTIGATION AND CONTROL OF GEODYNAMIC PHENOMENA

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Complex investigations and control of geodynamic processes and, accordingly, their apparatus equipment are of great importance. In order to provide proper metrological analysis, we have worked out the classification of geodynamic processes and estimated corresponding measurement errors. As a result, the main directions to improve the existing measuring equipment have been formulated. Various SSIA Metrology instrumentation relating to complex geodynamic investigations will be desribed.

QUALITY CONTROL CHALLENGES IN GPS POSITIONING ARRAYS

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Quality control in GPS reference stations of high accuracy is of critical importance to monitoring and positioning and involves two issues. First, statistical summaries for the operating characteristics of the measurement process of the reference receivers should be provided and second, an automatic and nearly real-time detection of ground deformation for each of the continuous operating stations should be achieved. The Technical University of Crete, Chania, Greece, is in the process of establishing a number of continuously operating GPS stations for supporting a high accuracy positioning service on the island. This paper investigates the automatic and in near real-time detection of deformation motion of GPS reference stations and ensures that the available deformation measurements contain information related to actual change, while monitoring the quality of the measuring process. The main isue is that of the detection of abrupt changes in some properties of the system under investigation. In this vein, several tasks have to be addressed. First, «residuals» or signals that will reflect direct changes in the systems have to be generated. Second, models have to be chosen based on the data window size (sessions), thresholds and weights etc. Third, parameters for the above chosen models have to be tuned; and fourth the integrity and stability of the statistical models have to be checked with real data. In this paper, continuous GPS data have been analyzed and evaluated for all the above quality procedures.

INHERENT ACCURACY OF 24-HR VLBI EOP MEASUREMENTS DERIVED FROM TWO SIMULTANEOUSLY OBSERVING NETWORKS.

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The international geodetic VLBI network, coordinated by the VLBI group at Goddard Space Flight Center, has begun an observing program called CORE (Continuous Observations of the Rotation of the Earth) that by 2001 will be carrying out 24-hr VLBI sessions every day to measure EOP. CORE is currently in a beginning phase observing four sessions per month. Two CORE-A sessions are simultaneous with NEOS (National Earth Orientation Service) VLBI sessions and two CORE-B sessions are scheduled on days adjacent to NEOS days. By having simultaneous VLBI estimates of EOP from two networks with no common sites, we will be able to probe the inherent accuracy of VLBI determinations of EOP. The CORE-B sessions will provide information about the continuity of EOP measurements. We currently have a set of 16 days since the beginning of 1997 with both CORE-A and NEOS sessions. On average the CORE-A 1-sigma formal errors are 2.8 microsec in UT1, 60 microarcsec in X-pole and 53 microarcsec in Y-pole. The corresponding values derived from the NEOS sessions are 3.3 microsec, 70 microarcsec and 52 microarcsec. The root-mean-square EOP differences for the 16 days are 6.2 microsec in UT1, 122 microarcsec in X-pole, and 106 microarcsec in Y-pole. In formal error units these correspond to 2.9, 2.1, and 1.6, respectively.

NEW APPROACH TO THE PROBLEM OF DETERMINATION OF ATMOSPHERIC REFRACTIVITY CORRECTIONS IN SPACE GEODESY

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New methods of determination of atmospheric refractivity corrections in space geodesy (astronomic observations, satellite laser ranging etc.) are proposed. These methods are based on integral approximation of ray optics equations which is free from basic limits of the known methods. In general, the new methods, in the first, have no need in using hypothesis on hydrostatic equilibrium of Earth's atmosphere; in the second, these methods does for arbitrary 3-D inhomogeneous Earth's atmosphere and for arbitrary zenith angles; in the third, in terms of new methods a rigorous analytical formulae for calculating of corrections by surface meteodata are used but not the empirical one (as in some known methods).

The accuracy of new methods was tested by numerical experiment (for zenith angles of 0...80 degree) with 125 radiosounde profiles obtained at the Kharkov's (Ukraine) meteorological station throughout 1979. It was shown that the new methods allow to determine atmospheric refractivity corrections in SLR with the systematic error 80...8 times smaller then wellknown Marini-Murrey's method and to determine a refraction angle with the accuracy 100...4 times larger than accuracy of the Pulkovo refraction tables.

AN ANALYSIS OF HIGH-ACCURACY TROPOSPHERIC DELAY MAPPING FUNCTIONS

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The correction of the propagation delay due to the neutral atmosphere has been recognized as the major modeling error for most of the radiometric space techniques used in precise geodesy, affecting mainly the height component of position. For low elevation angles, many of the existing mapping functions produce large errors and are therefore not suitable for those applications demanding the highest precision.

We have benchmarked five mapping functions acknowledged to be the most accurate of those currently available: those developed by the Harvard-Smithsonian Center for Astrophysics (CfA), Chalmers University of Technology (Ifadis), the Jet Propulsion Laboratory (Lanyi), the Massachusetts Institute of Technology (MTT), and Haystack Observatory (NMF) against ray traces of a one-year dataset of radiosonde profiles from 50 stations. From a station-by-station analysis, none of the mapping functions revealed themselves to be superior for all elevation angles. For elevation angles above 15 degrees, Lanyi, MTT, and NMF yield identical mean biases and the best total error performances. At lower elevation angles, Ifadis and NMF are clearly superior. As regards the r.m.s. scatter about the mean, Ifadis performs the best for all elevation angles, followed closely by Lanyi.

USAGE OF PHASE DELAY MEASUREMENTS PRODUCED BY VLBI FOR GEODETIC APPLICATIONS

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The method of VLBI allows to measure both group and phase delay observables. Phase delay is measured more precisely than group delay but is known only up to arbitrary integer number of phase turns, what makes it difficult to use it directly in LSQ parameters adjustment.
It is shown that for the best observing sessions phase delay ambiguity may be successfully resolved by straightforward usage of adjustments to the parameters obtained from the solution using group delay measurements. Refined algorithms which allow to weaken requirements to the quality of preliminary group delay solution are considered.
Estimates of EOP and station positions produced by phase delay and group delay solutions are compared. Differences obtained are discussed.

DIFFERENTIAL SATELLITE LASER RANGING MILLIMETER ACCURACIES USING CURRENT TECHNOLOGY

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We are presenting a new satellite laser ranging technique : the Differential Satellite Laser Ranging (DSLR). The principle : two (or more) satellite laser ranging systems are sharing one common laser transmitter. Recording the echo pulses arrival times at different locations, the corresponding baseline and relative station heights may be evaluated. Due to the differential approach, most of the error contributors present in the standard satellite laser ranging are minimized or not existing at all. The calibration, ground survey, orbit modelling, atmospheric correction, epoch reference and frequency errors are not contributing to the final solution, the satellite signature effects are minimized. Both the numerical and real data experiments verified the proper function of the DSLR technique and newly developed data processing algorithms. The application of this method is limited by the reflected signal footprint diameter on the Earth and by the possibility to interconnect the cooperating stations by the high quality coaxial cables.The DSLR technique may be used as an independent check of the ground survey, mount eccentricities and calibration procedure in collocation experiments.

ATMOSPHERIC CORRECTION FROM DUAL COLOR SLR

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Laser ranging to satellites provides the most accuratly measured ranges from a ground station to the satellite. The influence of the atmosphere so far is estimated by employing refraction correction models. Two color laser ranging techniques have the advantage that the refraction correction along the line of sight can be obtained directly from the measurements. By means of synchronising the deflection voltage of the streak camera with the mode locking frequency of the used Nd:YAG laser and locking both to a stable frequency standard, the streak camera represents a complete timing system for the simultaneous measurement of absolute ranges in the infrared and green wavelength domain. High resolution differential ranges are also readily available.

TRANSPORTABLE INTEGRATED GEODETIC OBSERVATORY TIGO AS A REALISATION OF A NEW FUNDAMENTAL STATION

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The Transportable Integrated Geodetic Observatory (TIGO) is designed as a Fundamental Reference Station. All relevant geodetic space techniques such as VLBI, SLR and GPS are employed. TIGO as a transportable system is planned to be operated for periods of minimum one or two years at remote sites in order to fill up gaps in the International Space Geodetic Network (ISGN). Currently the components are assembled at the Fundamentalstation at Wettzell. First observations with the SLR-module and the VLBI-module have been started. A test period of the entire system is planned for 1998 at the Fundamentalstation Wettzell in collocation with the Wettzell Laser Ranging System (WLRS) and the 20m-Radiotelescope for VLBI.

THE CII RING LASER PROJECT

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During the years 1995 and 1996 a new large ring laser as a prototye for geodetic applications has been built. It follows the basic concept of the Canterbury Ring Laser (CI), which has been developed over the last 10 years. In 1997, the full ring laser facility (CII) has been installed and extended work was carried out to establish longterm routine operation. The ring laser operates on a TEM(0,0) single longitudinal mode. To achieve stable operation conditions, amplitude and frequency stabilisation loops have been added to the ring. The conditions for the amplitude stabilisation are rather difficult, since the available output power of the ring laser is approximately 10 pW only. To obtain a stable optical operation frequency, a cavity length control to the order of 1 nm is required. The observed Sagnac signal is recorded in a continuous mode. Additional information, such as monument temperature, the atmospheric pressure and seismographic data is added to the data records.

FIRST STEPS TOWARDS REAL-TIME VLBI

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VLBI is an extremely precise modern geodetic technique for monitoring the Earth rotation and for the realization of the global reference system. However, the costs are relatively high and there is still a delay of one week minimum between the time of observation and the availability of results. If this gap could be shortened to a few hours this would allow to monitor relative station motions and the Earth rotation parameters in near real-time.
An important component of real-time VLBI is the direct transmission of the received signals from the radiotelescopes to the correlator or to a central computer for further processing. High bandwidth communication networks using optical fiber or communication satellites allow intra- and intercontinental transmission of signals at hundreds of Mbits/sec.
Another essential step towards real-time VLBI is a faster and semiautomatic data analysis. A concept of a knowledge-based system will be presented, which will support and guide the VLBI analysts to make the data analysis faster even by less experienced analysts. Some parts of the system have already been realized. Examples will be given of automatic editing of station logfiles before the weather and cable calibration data are entered into the VLBI databases.

INCREASING AUTOMATION OF GPS REFERENCE STATIONS WITH ASHTECH'S GEODETIC BASE STATION SOFTWARE

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As permanent, continuous, GPS geodetic networks increase and densify, it is becoming increasingly difficult to manage the recovery of the collected data by central processing facilities. Ashtech has addressed these issues with our new Geodetic Base Station Software (GBSS). GBSS has been specifically designed to work in concert with a co-located Windows NT Server and is capable of automatically generating, managing and distributing large amounts of GPS data.

GBSS software interfaces with Ashtech's GPS and GPS + GLONASS receivers, and it is capable of simultaneously creating many different GPS file types. These include single-frequency and dual-frequency files, trap files, NMEA files, ionospheric model files, diagnostic log files and compressed files. The software even allows the user to automatically generate files with different recording rates (e.g. 30 seconds, 20 seconds, 5 seconds, 1 second). This feature allows the user to have multiple data sets with different recording intervals for any given time frame.

Any of these files can then be made available to the user community *via* BBS, FTP, or a Web page. GBSS additionally employs push technology to automatically distribute any of these data files over the Internet.

AN ANALYSIS OF THE STOCHASTIC MODEL OF GPS OBSERVABLES

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Increased demands upon the accuracy of space geodetic measurement techniques call for, besides improved instrumentation, an improved modelling. The challenge is to develop a mathematical model for the processing of the data of the measurement system, that can meet these demands. In this paper we will give a procedure by which functional and stochastic model can be adapted to give an adequate description of the measurement data. The mathematical background will be given, followed by an elaboration upon the stochastic model, as the importance of a correct specification of this component is usually severely underestimated. As an example of an application, we consider (pseudo-range) code and (carrier) phase observables in a precise relative positioning set up, for some state-of-the-art geodetic GPS receiver pairs. The proposed procedure provides a powerful analysis of time series of these observables at 1 second rate. The functional model, as it is commonly used, is checked; unmodelled effects, if present, clearly show up. The stochastic behaviour of the GPS observables, with its cause in particular the receiver noise, is explored. It is shown what effects a sophisticated stochastic model should comprise. Refinements to the model currently in use are definitely necessary.

A satellite for submillimeter-accuracy SLR

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A new miniature spherical satellite has been developed for SLR with target errors less than 0.5 mm. The satellite named WESTPAC will be launched as a piggyback load on board of a Russian RESURS satellite scheduled for launch in mid-1998. The orbit will be a sun-synchronous one with a height of approximately 850 km. The 23.5-kg WESTPAC satellite, now completely tested and ready for launching, is equipped with 60 cube-corner retroreflectors and is based on a principle "one direction-one-reflector" which means that in any satellite's attitude and in any position relative to the SLR station only return signals from a single cube corner reflector can be received. To achieve this, each retroreflector is equipped with an individual blind limiting the angle of incidence of the laser beam.
Pictures of the WESTPAC satellite will be presented, as well as a list of its parameters.
Some proposals will be also presented for future satellites having still less target errors (of the order of 0.1 mm). Advantages and drawbacks of the proposed designs will be discussed.

A new approach to the problem of a transportable eye-safe SLR station for high-accuracy measurements

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A new approach is discussed for a design of a light-weight SLR station consisting of several separate units and operating at an eye-safe wavelength (1.55 mm). It uses a completely passive small-aperture optical system connected with the transmitter and receiver units by means of fiber-optical cables. A combination of a transmitter with a relatively high average output power (~10 W) and a high-sensitivity receiver with a fiber-optical preamplifier should provide a signal-power budget sufficient for ranging of all types of target satellites equipped with retroreflectors.
Block diagrams and return signal strength evaluations will be presented.

High Resolution Acquisition of Topographic Surfaces with the High Resolution Stereo Camera (HRSC).

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In the last 15 years digital techniques replaced more and more the analog photogrammetry analysis in daily work. Consequently the digital data collection becomes more important to the photogrammetric practice. Up to now analog aerial survey camera systems predominating the data acquisition. In near future the conventional analog survey camera systems will be replaced by digital cameras. At the Institute of Planetary Exploration of the German Aerospace Center (DLR) a High Resolution Stereo Camera (HRSC) has been designed for the Russian Mars96 mission. The HRSC instrument complies the fully capability characteristics for an digital aerial photogrammetric sensor. The scanning of the camera is based on an along track triple stereo concept. Besides the three stereo CCD's the HRSC camera has four multispectral and two photometry channels. Hence simultaneously high resolution stereo and multispectral data aquisition can be achived. To get high accurate position and attitude data of the aircraft-mounted camera system a GPS receiver is added and an inertial navigation system is mounted to the camera module. Beside the camera a complete photogrammetric and cartographic processing line including digital image matching, DTM and orthoimage generation, mosaicking and merging of multispectral data has been developed for the HRSC data processing. One target of a HRSC airborne campaign was the Sicilian vulcano Etna and the Lipari Islands. First result of the Etna and Lipari Island campagne is a DTM with high resolution and accuracy of the island Stromboli. The hard and software functionality tests demonstrated the qualification of the system for high resolution monitoring of topographic surfaces.

G16 Geodetic and geodynamic achievements of the CEI (Central European Initiative)

Convener: Sledzinski, J.
Co-Convener: Kostelecky, J.

INCORPORATION OF THE VERTICAL GRAVITY GRADIENT OBSERVATIONS TO THE DETERMINATION OF SEPARATION BETWEEN GEOID AND QUASIGEOID ON POLAND TERRITORY

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An application of observed gravity vertical gradient to the determination of the separation between geoid and Molodensky's quasigeoid is discussed in the paper. The author gives results of studies obtained from gradientometric measurements in a vicinity of Warsaw (Central Poland) and in submountainous area near Grybów (Cracow district - Carpathians). The values of ζ-N are not negliglibled for GPS levelling, too. Component depending on the gravity gradient achieves the value up to 2 mm, while the Bouguer anomaly contributes about 25 mm to ζ-N.

G16

PLATE KINEMATIC STUDIES IN ROMANIA USING GPS

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CERGOP (Central European Regional Geodynamic Project) was established to integrate geodynamic research in the Central European Region including 11 countries and using space geodetic techniques - mainly GPS. The geodetic network established - CEGRN (Central European GPS Geodynamic Network) provides a stable and reliable reference system. CEGRN actually represents a powerful tool in order to perform regional and subregional geotectonic investigations. In the CERGOP frame in Romania 4 main and 4 additional GPS stations were established. The GPS sites are situated on representative tectonic units. GPS observations were carried out at all 8 stations during the 1995, 1996 and 1997 CEGRN campaigns. This paper intends to present the first results with regard to plate kinematics in Romania based on the GPS results from BKG processing centre. Plans for the long-term observations and network densification are discussed.

CONTRIBUTION OF ASTRO-GEODETICAL OBSERVATORY IN JÓZEFOSŁAW TO EUREF AND GEODYNAMICAL STUDIES IN CENTRAL EUROPE.

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M. Figurski (Military Academy of Technology, Warsaw)

Astro-geodetic Observatory of the Institute of Geodesy and Geodetic Astronomy of the Warsaw University of Technology at Józefos³aw was incorporated in 1991 as the IGS station. Since 1993 the following permanent services have been maintained: GPS observations using Trimble 4000 SSE receiver and TurboRogue SNR-8000, tidal gravimetric observations using LaCoste Romberg gravity-meter model G and astrometrical observations with Zeiss telescope. Since January 1996 the WUT Processing Centre which is an integral part of the Observatory has started the systematic processing of network consisting of 18 sites, i.e. Józefos³aw, Borowiec, Lamkówko, Wroc³aw, Borowa Góra (Poland), Penc (Hungary), Pecny (Czech Republic), Mendeleievo, Svetloe (Russia), Wettzell, Insbruck (Austria), Kootwijk (Holland), Matsahovi (Finland), Onsala (Sweden), Matera (Italy), Modra Piesky (Slovakia), Ryga (Lithuania) and Joensuu (Finland). Paper presents the results of processing of data from these sites and contribution of the results to EUREF and some geodynamical projects in Central Europe.

PROGRESS IN ESTABLISHMENT OF THE UKRAINIAN-POLISH OBSERVATORY PIP- IVAN IN CHARNOHORA

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Creation of the international scientific centre on the base of the former astro-meteorological Observatory erected in 1938 at the Mount Pip–Ivan (2022m) was approved by decision of the scientific Ukrainian-Polish conference (October, 1996, Jaremche). Construction of the observatory has not been used since 1945, therefore it requires the significant repair-reconstruction works today. Considering the historical, scientific and cultural values of this complex, its location and environment it should be noted that observatory in Charnohora is unique and has no analogues. Architectural-archaeological investigations were executed and a respective project of restoration of the observatory was developed. A ground reconnaissance for making the geodynamic network around the Charnohora mountain belt was carried out. The first GPS measurements will be conducted in an astronomical house of the observatory in 1998 within the EXTENDED SAGET Project. A reconstruction of access road to the observatory from the main one will be begun in the near future, that will allow to accelerate the building works on its restoration. Realization of the permanent GPS, gravimetric, seismic, magnetic, meteorological, ecological and other measurements and studies will be provided here. Operation of the observatory will have a key role not only for studying geodynamics , bat also for the development of some natural sciences in the Carpathian region.

INSTRUMENTAL PHASE LAG DETERMINATION IN POLISH TIDAL STATIONS.

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The main limitation of the accurate determination of recent global Earth models determined from the tidal observations are currently due to the random observational noise, systematic errors of oceanic gravitation and loading corrections from the atmosphere and errors of instrumental phase lag corrections. This paper describes the experiments which were performed in three Polish tidal stations: Borowa Góra (907), Warszawa B (907) and Józefos³aw (909). First of them is equipped with the Ascania Gs-11 gravimeter modified by Bonatz and designated BN-17 and the rest of them are equipped with LaCoste&Romberg gravimeters G-648 and G-986 respectively. For these purposes we have used the step responce method invited and developed by prof. Wenzel. Two strategies of making steps were used: hand-made steps and with using the data acquisition system which consists of the PC, feedback and electronic step generation and step response digitization hardware. The description of the method and preliminary results are presented in the paper.

INFLUENCE OF THE GEOPHYSICAL EFFECTS ON THE RESULTS OF GPS DATA PROCESSING.

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M. Figurski (Military University of Technology, Warsaw)

Currently archieved subcentimeter accurasy of the GPS measurements makes people to verify the methods of the data processing and observations adjustment. Applying of the models which have been used so far is not sufficient for acquiring stable solutions on the level of one centimeter. Simple models of different geophysical effects implement to the solutions the noise which is compared to the values of the errors of determined coordinates. To solve this problem we could improve the adjustment by applying modelling of these phenommenas according to the newest theories. In particular one has to pay attention on the changes in time of the geophysical effects, interactions between them and their origins. This paper describes the geophysical effects which affect the GPS observations and some models used in GPS data processing.

APPLICATION OF GPS TECHNOLOGY TO THE ENVIRONMENTAL STUDIES.

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The Warsaw University of Technology (WUT) has been using GPS for over seven years to establish locations for geodetic surveying and environmental studies. In accordance with a recent plan developed by the Institute of Geodesy and Geodetic Astronomy the Józefos³aw station consists of a 3 GPS receivers (Trimble 4000SSE as a permanent receiver in IGS service, Turbo Rouge receiver as a control receiver and Trimble Community Base Station receiver with PFCBS software as a base station receiver) which works fully automatically. The base station (CBS receiver) is designated to service an area bounded approximately by a 300 km radius, and acts as a reference for roving field units operating in a GPS differential data collection mode. Some results of practical application of GPS technologies in water management, photogrammetry with video camera and some marine aimes are presented in the paper. We also present a new local area real time DGPS system.

STATUS OF ABSOLUTE GRAVITY MEASUREMENTS IN UKRAINE

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Absolute gravity measurements provide an important information for geodesy, geophysics, metrology and inertial navigation. SSIA "Metrology" has more than twenty-years experience in the developing and operation with both the free-fall and rise-and-fall absolute gravimeters. SSIA "Metrology" is authorized to establish new 10-15 absolute gravity stations to update the national base gravity network. Since the used gravimetric instrumentation is outdated to solve this problem, we have recently designed the State Special Standard and the State Verification Scheme to verify all the existing relative gravimeters. The main parts of that Standard are two symmetrical rise-and-fall absolute gravimeters. A prototype of the Standard (transportable absolute gravimeter GP-05) in 1992-1993 was used to establish the West, Central and East Gravity Calibration Base lines at the Polish Gravity Network with the expected errors up to 30 μGal. First results obtained with the new transportable gravimeters at the newly created station "Kharkov" in Jan.-Feb. 1997 point out ability to measure an absolute gravity value in the very noisy conditions of a large industrial city with the errors of order 10 μGal (random) and 8 μGal (systematic). Now we are looking for a possibility to take part in primary or secondary intercomparisons of absolute gravimeters. Having created a few absolute stations in Ukraine, we would be able to connect the gravity network of Ukraine with the Central European ones. In particular, we are very interested to join in the nearest future such campaigns as the UNIGRACE Project (Unification of Gravity Systems in Central and Eastern Europe).

RECENT GEODYNAMICS OF ESTERN SUDETY MOUNTAINS AND SUDETY FORELAND

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The Sudety Mts. and Sudety Foreland envelop the area of north-east margin of Bohemia Massif with complicated block-type geological structure. Contemporary orographic image of this region results from Tertiary (Miocene, Pliocene) tectonic movements. A lot of earthquakes are registered in historical period. These facts and modern quantitative and qualitative data confirm that tectonic activity still is going on. In 1992 an investigation of the recent movement of the upper layer of lithosphere of the areas in Eastern Sudety Mts. and Sudety Foreland was begun. The following areas were investigated: Śnieżnik Massif, Paczków Graben and Stołowe Mts. In 1996 these separate projects were included into the GEOSUD project. Repeated observations were carried out using GPS, gravimetric, and geodetic methods. The results of this investigations and preliminary interpretation are presented in the paper.

REALIZATION OF THE HUNGARIAN NATIONAL GPS NETWORK

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Hungary as one of the first East-European country joined to EUREF in 1991. In the same time a 24-point frame network was also established. The further densification of the GPS network was delayed, it was started only in 1994 with site selection. The Hungarian National GPS Network (OGPSH) is based on the existing geodetic network points, where GPS measurements are possible. New sites were monumented only where suitable existing site was not found. The mean point distance is about 10 km. This relatively dense distribution was chosen, because of its more efficient field measurement technique. More than 1100 point were selected and had been measured in three campaigns between 1995 and 1997. In the campaigns 9 observer group were participated and measured 5-6 session per day. The GPS data were processed by Trimble's GPSurvey program, the network adjustment was done with our own software. The GPS coordinates are in the ETRS89 system, the horizontal position accuracy is at the cm-level.
Almost 300 site have levelled height. Based on the technique developed at our Observatory all OGPSH site was furnished with sea-level height using the GPS-gravimetric geoid. The height component accuracy is about 1-3 cm.
Also a new, GIS-based database was developed, which containes all relevant information and available for the users.

TRACKING AND DATA PROCESSING AT THE GPS STATION UPAD

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The permanent GPS station UPAD of the University of Padova was installed in 1994 to support research projects on space technologies and satellite geodesy, and to serve as a training facility for students in Earth Sciences and Engineering. In December 1997 the TRIMBLE 4000 SSE receiver and the geodetic antenna were replaced with a TRIMBLE 4000 Ssi receiver and chocke ring antenna, and a control software Universal Reference Station (URS) under OS/2 WARP 4. Asynchronous data access is offered via a Bulletin Board System with modems connected to an intelligent DigiBoard PC/4Xe multiport board. Internet access occurs via the University's high speed LAN. Plots describing the receiver's performance are computed with the program QC of UNAVCO and appear on a dedicated WEB page. The acquired data are ftp'ed daily to the IGS Central Bureau in Pasadena, California and to the CERGOP Data Center in Graz. UPAD contributes to IGS, CERGOP and the Italian Permanent GPS network of the Italian Space Agency. In 1997 the University of Padova joined UNAVCO. Data processing with the Bernese 4.0 software of the University of Bern concentrates on a alpine network comprising the permanent stations in Grasse, Torino, Zimmerwald, Pfaender, Hafelekar, Trento, Padova, Graz, Venezia and Matera. The daily network solutions are stacked and eventually combined in weekly solutions, and time series of baselines are generated.

STRATEGY OF GPS DATA PROCESSING IN LOCAL GEODYNAMICAL NETWORKS

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Geodynamical research carried out by the Department of Geodesy and Photogrammetry of Agricultural University of Wroclaw base on repeated yearly satellite observations of local GPS networks. Placement of the observation points adapted to specific geological and tectonic conditions cause big differences of base-line lengths. Geometric heterogeneity of the networks requires a specific strategy of observations planning and data processing (data from various receivers, network construction, ambiguity solution, ionosphere and troposphere modelling, normal equations solution, connection with EUREF/IGS permanent stations and results distribution). In the paper the results of GPS data processing of geodynamical research network GEOSUD using BERNESE v4.0 software are presented.

ARE TERRESTRIAL LEVELLING AND SATELLITE GPS NETWORKS WELL-MATCHED WITH THE RECENT DYNAMICS OF THE POLISH TERRITORY

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Paper discusses the question whether terrestrial vertical network of the precise levelling and the newly established geodynamic satellite GPS network are adjusted to the tectonic structure of the Polish territory. Considering that the traditional precise levelling network has been established to cope with purely geodetic demands, its usefulness for monitoring the tectonic vertical movements of the Earth's crust is discussed. The maps of the vertical crustal movements of 1971 and of 1985 are analysed. Geodynamic networks based on satellite GPS observations established on the Polish territory during last decade in the frames of CEI and other Regional Projects are discussed against a background of the tectonics of the Polish territory.

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RTK-DGPS FOR MILITARY AND CIVIL AVIATION IN POLAND

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A project on real-time-kinematic DGPS has been recently launched in Poland. A pair of DGPS stations is proposed to become operational late 1998 as an experimental part of the system. The system is designed for both military and civil users. It has to satisfy demands of the Polish aviation for precise navigation under all weather conditions. The broad programme of test measurements is developed to assess all particular segments of the system including equipment of the reference station and on-board installations as well as transmission of the differential corrections. The system will assure all international standards of accuracy and will fulfil all security requirements.

APPLICATION DGPS SYSTEM FOR SURVEYS OF HYDROTECHNICAL OBJECTS

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The Baltic Sea is connected with the port of Szczecin by a 65-kilometre fairway for deep-drawing ships. In order to ensure nawigational safety in this area requires, continuous hydrotechnical surveys have to be performed. This, in turn, requires accurate positions to be determined. In 1996 a DGPS reference station was established. The station transmits differential corrections on VHF channel 87 which provide for increased accuracy of hydrographic and hydrotechnical surveys.
The article presents data from a test in which a DGPS receiver was used. The receiver was integrated with a multi-beam echosound for the location and full identification of dimensions and shapes of a submerged hydrotechnical object in the fairway. The tests have proved that the DGPS reference station was duly and correctly located. It allows conducting underwater work with great accuracy.

TATRA MOUNTAINS WITHOUT BORDERS

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The reference geodetic network CEGRN in Central Europe was established for studying of interplate tectonic deformations of European tectonic plate. This network serves as a regional reference frame for local tectonic investigations. The Project "Tatra Mountains without borders" is a local project for studying of 3D displacement of points located in Tatra Mountains without Slovak-Polish border. The GPS network consists from four higt levels. First higt level is about 700m, second about 1 600m, third about 2 000m and fourth on the top of Tatra Mountains. The first GPS measurement campaigns were carried out by Department of Theoretical Geodesy, Slovak University of Technology Bratislava, Institute of Geodesy and Cartography Bratislava and Institute of Geodesy and Geodetic Astronomy Warsaw University of Technology in September 1997. The local quasigeoid was determined from gravimetric data will be tested by GPS/levelling data.

LONG-PERIOD SOLUTIONS OF RESULTS OF THE GOP EUREF LOCAL ANALYSIS CENTER

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Since January 1997 the Geodetic Observatory Pecný participates in the EUREF Permanent network project as a Local Analysis Center (LAC). During this period the GOP LAC produces weekly solutions of specified permanent subnetwork as its official results.
The method of creating a long-period solution based on weekly LAC results is discussed. Using the Sequential Least-Square Adjustment implemented in the program ADDNEQ of the Bernese GPS software (BSW) allows to add the velocity parameters to the coordinate estimations. The new implementation of the program ADDNEQ (BSW Ver. 4.1) is compared with the old one (BSW Ver. 4.0).

GEODYNAMIC INVESTIGATIONS IN THE SREA OF RIKSK RIFT (THE UKRAINIAN CARPATHIANS)

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The Riksk tectonic rift is situated in the Ukrainian Carpathians within the bounds of the river basins of the Rika and the Tereblya which are the right tributaries of the Tusa. The riverbeds of the Rika and the Tereblya are practically parallel and they are situated at the distance of 6-20 km. But the differences of the marks of the absolute altitudes of the riverbeds exceed 200m. This is a unique phenomenon in the Ukrainian Carpathians. It confirms the activity of the rift in the past. The natural overfall of the altitudes is successfully used for construction of the Tereblya-Riksk hydroelectric station and for organising Tereblyansk reservoir. Sharp changes in the water level of the Tereblyansk reservoir leads to the changes of the hydrodynamic loading in the area of the Riksk rift. It becomes apparent in the deformation of the earth surface (crust) and the constructions of the Tereblya-Riksk HES. The results of the repeated observations and geodesic and geomorphologic investigations prove this.

THE CENTRAL EUROPE GEODYNAMICS PROJECT (CERGOP): MAIN ACHIEVEMENTS 1995-98

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CERGOP has integrated a considerable part of geodynamic research in Central Europe, established a large number of collaboration, exchange of information and perhaps most notably - mutual trust and understanding among the participants. The Central European Geodynamic Reference Network (CEGRN) based on GPS measurements has been established consisting of 31 sites in 11 Central European countries. Four epoch measurements were carried out spanning 3 years from 1994-97. The results of the yearly epoch measurements on the CEGRN are the basis for a number of studies. . There are 12 permanent GPS stations operating in the area. 10 multinational CERGOP Study Groups (CSG) are active and some of their results is presented here. The CERGOP Data Centre functioning efficiently and smoothly in Graz, Austria. Processing of the observational data are carried out in the CERGOP Processing Centres (Bratislava, Frankfurt am Main, Graz, Pecny, Penc and Warsaw). The data analysis is done within CSG4. Important achievement is that the accuracy of the CEGRN epoch coordinates is on the sub-centimeter level. Publication of the proceedings is carried out by the Warsaw University of Technology, Poland, quickly and efficiently in the *Reports on Geodesy*. There are external users of CEGRN already. Most notably the University of Karlsruhe and the Italian Space Agency (ASI) are using CEGRN data for geophysical studies. We are also aware of a number of local deformation studies in the participating countries where CEGRN sites are used as reference.

DGPS on The Baltic Sea - the Hydrographic Experience

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The paper presents the status of DGPS network on the Southern Baltic and the degree of its implementation for the hydrographic requirements. The operation zones as well as the accuracy and availability of the reference stations were investigated.

It must be underscored that in the Polish exclusive economic zone, and even on the coast, signals from the Swedish and the Danish stations were received.

THE EFFECT OF IONOSPHERE MODELING ON THE ACCURACY OF GPS SINGLE-FREQUENCY OBSERVATIONS.

M. Figurski (Military University of Technology, Warsaw)

The analysis of the possibility of applying different ionosphere models (ranging from global to local) to improve the accuracy of determinations from single-frequency measurements of GPS. The method proposed in the paper permits increasing the accuracy of determinations of position of single-frequency GPS receivers.

ANALISYS OF A SUB-NETWORK OF STATIONS FROM 4 YEARS OF CERGOP GPS CAMPAIGNS.

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CERGOP project started in 1994 with the purpose of monitoring the central-eastern part of Europe. Since that time GPS campaigns were carried out one per year. Recently CERGOP has extended the network to the southern part of Europe. The extension of the network is making suitable its integration with the existing permanent network in Italy and is strongly encouraging the involvement of other countries in the project. For these reasons Italy are evaluating the opportunity to play a major role in the next phase of CERGOP project which plans to address its efforts in a wider field of applications. As contribution of Matera Space Geodesy Center (CGS) to the project, a sub-network of CERGOP stations has been analyzed and the major results in terms of coordinates and baselines time-series, together with the processing strategy, are showed in this paper.

THE CONTRIBUTION OF THE EUREF- AND EUVN-GPS-CAMPAIGNS TO THE MAINTENANCE OF THE GEODETIC REFERENCE SYSTEM IN CENTRAL EUROPE

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From 1989 to 1997 a new GPS-orientated European Geodetic Reference System of high accuracy was established (EUREF). In order to maintain and to improve this frame especially in height in May 1997 a large GPS-Campaign including approximately 180 sites was observed which combines about 60 EUREF-sites with about 60 tide Gauges and about 60 Nivellitic Nodal Points. To obtain daily control about 65 permanent GPS-stations are operated all over Europe which result in very precise positions reflecting any significant change.

FINAL RESULTS OF CEGRN OBSERVATIONS CAMPAIGNS.

L. Ferraro (Agenzia Spaziale Italiana)
M. Marjanovic (Drzavna Geodetska Uprava, Croatia)
L. Mervart (Geodetic Observatory Pecny, Czech Republik)
M. Becker, T. Rus (Bundesamt fuer Kartographie und Geodaesie, Germany)
T. Pany (Institute of Space Research, Austrian Academy of Sciences)
G. Stangl (Federal Office of Meteorology and Surveying, Austria)
A. Kenyeres (FOMI Satellite Observatory Penc, Hungary)
J. Hefty (Department of Theoretical Geodesy, Slovak Technical University)
J. B. Rogowski (Institute of Geodesy and Geodetic Astronomy WUT, Poland)
M. Figurski (Military University of Technology, Poland)

Central European GPS Reference Network (CEGRN) was established as a part of Central Europe Regional Geodynamics project (CERGOP). Starting with 1994 yearly CEGRN campaigns have been performed lasting for about five days. Observations of some permanent stations of IGS and EUREF have been added to the field data, thus forming the CEGRN network for geodynamic research. The network computation has been carried out by six analysis centres. Which have used a common processing strategy and BERNESE v. 4.0. Common data set was used except numbers of surrouding IGS stations. Troposphere parameters have been estimated every two hours using 10 cm absolute constraint, 2 cm relative constraint and Saastamoinen troposphere model as a priori model. The adjustment was done by constraining the ITRF-94 coordinates of Wettzell. Official CEGRN products consist of (1)individual Processing Centres solutions, (2)combination of free network solutions, (3)solutions transformed to CEGRN Reference Frame and their analysis are presented in the paper.

AN ATTEMPT FOR GEOKINEMATIC INTERPRETATION OF GPS MEASUREMENTS IN THE CEGRN NETWORK

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The Central European GPS Geodynamic Reference Network (CEGRN) was established in the frame of the CERGOP project in 1994 in order to study the relevant tectonic features in the Central European region. The CEGRN network consists of 31 official sites distributed in 11 countries. The primary tool for this investigation is the GPS technique. So far four GPS campaigns were organized between 1994 and 1997. The GPS data had been processed by several processing centers according to a unified strategy. The FÖMI Satellite Geodetic Observatory was one of the Processing Centers. This paper summarizes the results of the processing activity but it focuses on the possible interpretation of the four-epoch GPS data set. An attempt was made to determine the velocities of the CEGRN sites and detect the strain distribution in the area under investigation providing quantitative information for the recent geodynamic model of the Central European region. Although the CERGOP project terminated in 1998, the activities initiated in its frame planned to be continued in the future in order to provide more realistic geokinematic picture on the Central European region.

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CRUSTAL DEFORMATIONS IN THE PANNONIAN BASIN INFERRED FROM GPS MEASUREMENTS

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The formation and the evolution of the Pannonian basin is one of the main events of the Neogene tectonics of Central and Eastern European region. The Hungarian GPS Geodynamic Project was commenced at the beginning of the nineties to investigate the recent crustal deformation in the Pannonian basin. The Hungarian GPS Geodynamic Reference Network (HGRN) had been established in 1991. From that time four surveys were carried out and after six years of measurement we started to evaluate our results. During the interpretation the determination of velocity field and strain distribution is carried out. Based on the calculated deformations we try to mark out faults and areas having active recent tectonics. We try to define the recent tectonic regime of the basin as well. Furthermore we compare our results with that of other methods and finally we attempt to summarize a recent tectonic model for the Pannonian basin based on the four HGRN GPS campaigns.

GEOMETRICAL INTERPRETATION OF THE QUASIGEOID ON THE TERRITORY OF THE CZECH REPUBLIC

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The surface of the local quasigeoid, constructed at the Research Institute of Geodesy, Topography and Cartography on the basis of heterogenous data (astronomy, gravimetry) is considered as geometrical surface. For that surface the metric tensor, Christoffel symbols, Gaussian and mean curvatures were computed. The results are correlated with geomorphology and geotectonic structure of the territory of the Czech Republic.

ESTIMATE OF SITE VELOCITIES FROM CEGRN GPS CAMPAIGNS REFERRED TO CERGOP REFERENCE FRAME

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Precise geodetic GPS network CEGRN (Central European GPS Reference Network) for studies on geodynamics in the territory of Central Europe is provided within the Central Europe Regional Geodynamics Project (CERGOP). Coordinates and covariance matrices from four CEGRN epoch campaigns from 1994 to 1997 are used to estimate velocities of about 30 sites observed. We apply the global staistical model for estimation of site coordinates and site velocities on the basis of epoch GPS observation campaigns. The model enables estimation of single site velocities as well as the velocities common to group of sites. The velocity estimates are referred to CERGOP reference frame that allows to interpret the derived quantities as site movements relative to the Central European part of the Eurasian tectonic plate. Resulting horizontal velocities of the monitored sites are of order of several mm per year. Their statistical significance is discussed.

IRREGULAR CHANGES IN EARTH ROTATION PARAMETERS.

M. Kruczyk (Institute of Geodesy and Geodetic Astronomy WUT, Warsaw)

Few numerical methods were used to detect irregular changes both in the polar motion and length of day in two combinations of everyday ERP from IERS and JPL (R. Gross). Signal amplitudes only slightly exceed observational noise so the most helpful time spectral analysis remains MESA with weight windows. Some non tidal short period oscillations were identified and filtered. Long term changes of individual oscillation amplitudes show conformity of modulation. First trial to detect irregular changes was the least square adjustment of the most energetic oscillations to obtain amplitude and phase fluctuation. Much more successful approach appeared long time series prediction. The difference between prognosed and observed value was assumed as a convenient determinant of irregular changes. Three methods of prediction were applied to mentioned series: (1)autocovariance with the robust approximation, (2)autoregressive reccurention with RVC criterion, (3)autoregressive with least square coefficient adjustment. Good correlation of all results confirm credibility of prediction as the tool for irregular changes survey. In same periods of time prognosis deviations are few times bigger then normally and higher then statistical expectations. Notable amount of prognosis deviation data allowed to compare prognosibility of different parameters, evaluate quantity of data and test numerical algorithms. But first of all we can search now for correlations between irregular changes of ERP and the alternations in global atmospheric and hydrospheric circulation - connection with the seasons and El Nino is highly probable. This paper presents subseqent steps of calculations, final results and first conclusions.

USE OF GPS MEASUREMENTS FOR DETERMINATION OF GRAVIMETRIC TOPOGRAPHIC CORRECTION

B.Kalinowska-Śledzińska, M.Barlik, K.Czarnecki, S.Margański, A.Pachuta, J.Walo.
(Warsaw University of Technology, Institute of Geodesy and Geodetic Astronomy, Warsaw, Poland)

The problem how to replace the classical horizontal and vertical surveys, indispensable for the determination of the gravimetric reductions and corrections, by the satellite GPS measurements is discussed in the paper. The theoretical considerations are supported by the results of the practical test surveys performed in the Geodynamical Test Field located in the hilly area near Grybów, south Poland. For field test measurements there were used electronic total stations, levelling instruments and satellite GPS equipment capable to apply the quick measuring technologies in real time kinematic mode.

COMPARISON OF DIFFERENT TYPES OF GPS RECEIVERS AND ANTENNAS.

L. Kujawa (Institute of Geodesy and Geodetic Astronomy WUT, Warsaw)

Receivers tests were performed at the Institute of Geodesy and Geodetic Astronomy Warsaw University of Technology to compare some different types of receivers and antennas under A/S conditions. To perform the test we assembled six receivers: TurboRogue SNR8000, Ashtech Z-XII-3, Trimble 4000SSE ,Trimble 4000SSi and Leica SR9500 . Two basic types of tests were performed: zero baseline and short baseline tests. Detailed results of tests are described in the paper.

ACHIEVEMENTS AND PROSPECTS OF GEODYNAMIC STUDIES ON THE CARPATHIAN TEST FIELD

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Complex geodetic, geophysical and geological studies in seismoactive part of the Ukrainian Carpathians are directed on the study of modern geodynamic processes, particularities of deep construction of lithosphere and forerunners of earthquakes. Geodetic network for the recent movements of the Earth's crust studying was laid there at the beginning of the 70's. The GPS measurements on nine points were conducted in 1993. Their comparison with linear measurements has allowed to receive the characteristics of horizontal deformations of the Earth's crust. The map of gradients of velocities of vertical deformations is created by the results of repeated levelling. Six complex geophysical and four seismic stations are working in the continuous conditions. Inclinometric and deformographic observing are carried out in a special gallery. Gravimetric and geomagnetic measurements are conducted on the special points and fundamental bench marcs. The zones-indicators of changes of tense-deformed condition of the lithosphere for a period 1982-1995 are determined on the basis of geomagnetic monitoring. Technology of the active fault zones studying by the tectonomagnetic method is developed. Realization of repeated geodetic measurements on all test fields, as well as expansion of a network of complex geophysical stations as well is planned.

UNIFICATION OF GRAVITY SYSTEMS OF CENTRAL AND EASTERN EUROPEAN COUNTRIES - UNIGRACE

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Gravity is considered as a constant in several metrological problems, it enters the definition of height systems and is commonly used in exploration of mining and energy resources in Central and Eastern Europe. The differences between gravity systems in Eastern and Central Europe are so large that they strongly affect mapping, surveying and navigation in a European scale as well as the vertical datum definitions and height systems. Because of the present trends of political and economical unification in Europe also formerly classified gravimetric data are becoming available. It is therefore mandatory to study system differences and to unify them.
The project UNIGRACE aims at solving this problem in the only possible way by carrying out absolute gravity measurements with the most advanced technology at selected sites in the countries concerned. In a joint effort five European groups from Austria, Finland, Germany, Italy and Poland using their absolute gravimeters and partners from Bulgaria, Croatia, Czech Republic, Hungary, Romania, Slovakia and Slovenia will determine sufficiently large gravimetric networks in Central and Eastern Europe in a relatively short time. As a result, a unique gravity system in Europe will be available.
The European Commission is granting the project for 3 years after signing the contract in December 1997. The Project starts after the first working conference in Frankfurt a. M. in February 1998.

PRESENT STATUS OF ESTABLISHMENT OF NAVIGATION DGPS SYSTEMS IN EUROPEAN COUNTRIES

Stanis³aw Oszczak (Institute of Geodesy, Olsztyn University of Agriculture and Technology, 10-957 Olsztyn, Poland).

The information on some applications of DGPS methods to establishment of navigation systems for marine, aviation and land navigation purposes in EU and Central European Countries is given. The integration and standardization aspects of National and Local Area Augmentation Systems (LAAS) with European Project EGNOS beeing a part of GNSS-1 is discussed.
The status of projects and problems of creating of DGPS permanent reference stations network in Central Europa is described. The impact of DGPS/DGLONASS integration to give availability, integrity, continuity and accuracy for navigation and positioning determinations is also presented.

CERGOP AS A REGIONAL NETWORK FOR THE MAINTENANCE OF THE EUREF REFERENCE FRAME.

J. B. Rogowski (Institute of Geodesy and Geodetic Astronomy WUT, Warsaw)
M. Figurski (Military Academy of Technology, Warsaw)

In 1987/88 the IAG EUREF Sub-commission designed and defined a new precise Geodetic Continental Reference System ETRS. In 1994 at the EUREF Symposium in Warsaw the use of the European permanent stations for the European reference frame was recognised. All organisations performed permanent GPS observations in Europe were invited to make available their observations and analysis centres were invited to process European sub-networks consisted of those permanent stations. In May 1996 the IGS officially accepted the EUREF response to the IGS call for densification of ITRF by regional GPS analysis. At present EUREF permanent network consists of nearly 60 stations, 7 Local Analysis Centres performed processing of the data from particular EUREF sub-networks.7 EUREF permanent stations are also the CEGRN/CERGOP sites. Results of combinations of CEGRN epoch solutions and EUREF solutions are presented in the paper. Role of combination CEGRN and EUREF solutions in the maintenance is also discussed.

PERMANENT GPS STATIONS IN CENTRAL EUROPE FOR PRECISE (REAL-TIME) POSITIONING

P. Pesec
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The growing demand for precise geocentric coordinates in real-time to be used as input for the guidance and control of moving objects forces the update and densification of satellite reference stations. GPS (eventually combined with GLONASS) will keep the privilege at least for the next five years.
The project CERGOP of the Central European Initiative CEI has stimulated first steps for the establishment of a GPS-reference network in Central Europe. During the next phase this network should be updated in order to meet forth-coming interdisciplinary challenges, scientific as well as commercial, the accuracy level ranging from some metres down to the millimetre level.
The paper discusses the requirements for a future CERGOP-2 GPS reference network, required to cover all aspects, leading from a simple position finding via precise navigation to geodynamical monitoring. As an example, the present status of the Austrian multi-purpose GPS-network and the ongoing developments are shown.

SOME CHARACTERISTICS OF DETAILED GRAVITY FIELD FOR THE TERRITORY OF THE CZECH REPUBLIC AND THEIR GEOPHYSICAL IMPLICATIONS

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Two of the earth's gravity field characteristics - geoid heights and vertical deflections computed for the territory of the Czech Republic from a high resolution model based on terrestrial and satellite data using different gravity and topographic reductions have been used for a correlation analysis incorporating several geophysical fields - recent crustal movements, heat flow and zones of macroseismic mobility. The results are compared with those previously obtained with less detailed terrestrial data.

CURRENT STATUS OF REALISATION OF SCIENTIFIC PROGRAMMES IN GEODESY AND GEODYNAMICS OF THE CEI SIXTEEN COUNTRIES

Janusz Śledziński (Warsaw University of Technology, Institute of Geodesy and Geodetic Astronomy, Warsaw, Poland)

The broad programme of geodynamic research initiated by CEI (Central European Initiative) member countries is outlined in the paper. The achievements in the Project CEI CERGOP (Central Europe Regional Geodynamics Project) are shortly discussed. The main objectives of the Project are: to integrate the geodynamic research in the region of Central Europe based on high accuracy space geodetic measurements, to provide a precise geodetic frame CEGRN (Central European GPS Reference Network) for studies of geodynamics of Central European area (Pannonia Basin, Teisseyre-Tornquist Zone, Carpathian Orogenic Belt, Subalpine Region and Bohemian Massif) and to collect observations for studies and interpretation of geodynamic interactions in Central Europe. The following countries participate in the Project: Austria, Croatia. the Czech Republic, Germany, Hungary, Italy, Poland, Romania, Slovakia, Slovenia and Ukraine. Four GPS observation campaigns of the CEGRN were organised in 1994, 1995, 1996 and 1997. Another CEI Project UNIGRACE concerns unification of the gravity systems in Central and Eastern European countries. The activities of other CEI WGST Section C "Geodesy" working groups (WG on University Education Standards, WG on Satellite Navigation Systems) are also outlined in the paper.

THE GPS CAMPAIGNS OF CERGOP - COMBINED PRODUCTS OF 1994-1997

G. Stangl (Federal Office of Metrology and Surveying, Lustbuehelstrasse 46, A-8042 Graz, Austria)

The GPS measurements of the CERGOP campaigns 1994 to 1997 have been processed by several centres using a frame of common rules. With an accuracy of better than 10 mm tectonic movements should be detectable in most parts of Central Europe. Using a free network comparison as well as an evaluation in a special precise reference frame some movements may significantly deviate from the common rate of plate velocities.

SIX GPS CAMPAIGNS OF THE PROJECT EXTENDED SAGET

Janusz Śledziński (Warsaw University of Technology, Institute of Geodesy and Geodetic Astronomy, Warsaw, Poland)

The international project EXTENDED SAGET was launched by the Institute of Geodesy and Geodetic Astronomy, Warsaw, Poland in 1991 as a continuation and extension of the Polish geodynamic project SAGET (Satellite Geodetic Traverses) initiated by this Institute in 1986. Six 5-day GPS epoch observation campaigns were organised every year since 1992. About 50 European stations from 12-14 countries take part every year in the Project. The observations are processed in the Institute Processing Centre. This Processing Centre currently acts as (1) Regional Network Associate Analysis Centre, (2) EUREF Local Analysis Centre and (3) CEI CERGOP Processing Centre. Since 1994 the campaigns of EXTENDED SAGET have been coordinated with the campaign of the CEI CERGOP (Central Europe Regional Geodynamics Project) Project.

SOME NOTES ON THE FUTURE NAVIGATION SATELLITE SYSTEM ARCHITECTURE FOR MARINE PURPOSES

Marek Szymoński

Merchant Marine Academy of Gdynia, Poland

This paper provides an advice on the evaluation of more than one Satellite System concept for marine navigation.
A very wide range of different types of ships performes different tasks at sea. The transport, scientific, technological, economical and social development are generating new specific tasks at sea which result in future standarization of navigation operation.
The standards for navigation are very precisely specified by regulations made by the International Maritime Organization (IMO). Some of them, concerning the Satellite Systems of Global Marine Navigation are presented in the paper.

MONOGRAPHIES ON GEODYNAMICS OF A PART OF CEI TERRITORY

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Within the Section C „Geodesy" of the Central European Iniciative the CERGOP Study Group 8 (CSG8) „Geotectonic analysis of the region of Central Europe" was created. The cooperation is aimed at preparation of monographies of chosen geological provinces in Central Europe. Whole region was divided in five provinces as follows: Bohemian Massif, Tesseyre-Tornquist zone (and Eastern platform), Eastern Carpathians, Southern Carpathians (Dobrogean Orogen, Moesian Platform and Northern Balkanides) and Pannonian Basin. The preparation of Monographies was coordinated by one responsible scientist for each province with collective of collaborators - specialists in geology, geophysics and geodesy. Main goal is to summarize the present knowledge on structural properties and geodynamics of whole region with recommendations for further scientific studies by means of advanced technique. These studies will be aimed at definition of geodynamical model with consequences by solution of environmental problem in Central Europe. The set of monographies is ready for print and main achievements are discussed in present paper.

ATTEMPTS AT UPGRAGING UNIVERSITY EDUCATION STANDARDS IN THE CEI COUNTRIES

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Working Group of the CEI Section C 'Geodesy' on "University Education Standards" was established in 1994. The Working Group goals are focused on upgrading the education level in the field of geodesy and land surveying in the CEI countries. Paper presents the problems considered during the Working Group Symposia held at the Department of Geodesy, University of Ljubljana. The first Symposium of 1996 was devoted to the topic of "Education in GPS for Geodesy and GIS", and the second to "DGPS in Engineering and Cadastral Measurements – Education and Practice". Paper summarises the Symposia and announces The Working Group planes (A Workshop on "Education in GPS for GIS" is planned to be held in Grybów, Southern Poland, summer 1998).

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Please send your entry to the EGS Office not later than 1 December.

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